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Mohawk River Bridge, Interstate Route 87, near Albany, N.Y.

IN THIS ISSUE: Economic costs of motor-vehicle traffic accidents.



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U.S. DEPARTMENT OF COMMERCE

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BUREAU OF PUBLIC ROADS

BERTRAM D. TALLAMY, Administrator

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Contents of this publication may be reprinted. Mention of source is requested.

A Symposium on Traffic Accident Costs

In this issue, major findings of motor-vehicle accident cost studies conducted in Massachusetts and Utah are discussed. Cost data are classified on the basis of severity of accidents and are further related to the activities of persons involved in accidents, to the highway systems on which the accidents occurred, and to the types of vehicles involved.

Placing a dollar value on losses resulting from traffic accidents in no way minimizes the personal tragedy of either traffic fatalities or serious injuries; it is simply a means of identifying and measuring financial losses that in turn can be used as a tool in the planning of both highway safety and highway improvement programs.

Of the four articles presented here, three report findings of the Massachusetts accident cost study and the fourth applies to a similar study made in Utah. The findings are based on data from only two States, and whether similar patterns or trends obtain in other States can only be determined when studies now under way or planned for the future are completed. The data presented, however, are believed to be generally indicative of what may be expected in other States of similar characteristics.

In this analysis, economic costs are confined specifically to direct costs of traffic accidents. Other direct costs in connection with non-traffic accidents and traffic and non-traffic incidents are excluded. Non-traffic accidents are those involving motion but not occurring on a public roadway. Traffic and non-traffic incidents are mishaps occurring on and off public roadways, not involving motion, and attributable to vandalism, fire, and acts of God.

Direct costs are composed of the money value of damage to property; hospitalization; services of physicians, dentists, and nurses; ambulance use; medicine; work time lost; damages awarded in excess of other direct costs; attorneys' services; court fees; and other lesser items.

Another large segment of costs borne by the public are indirect costs. Although not a part of this analysis, they must be considered in any total view of accidents. They include such items as loss of future earnings as a result of injuries causing death or permanent disability, overhead cost of motor-vehicle accident insurance as well as certain other types of insurance with accident coverage, property damage indirectly resulting from an accident, illness or death of a person not involved in an accident but traceable thereto, public aid for care of indigent persons injured in motor-vehicle accidents, and expenditures for driver training and other accident prevention activities.

The economic costs of motor-vehicle accidents are discussed from four aspects: First, the cost in relation to persons involved in accidents; second, the cost in relation to the road systems; third, the cost in relation to passenger cars and trucks; and fourth, the cost in relation to highway planning and improvement.

The Economic Cost of Traffic Accidents in Relation to the Human Element (p. 34) discusses the impact of traffic accidents on the total population of Massachusetts. It shows that if existing traffic accident rates are not reduced, every individual in the entire population of Massachusetts would be in a motor-vehicle accident at least once every 13 years, or 5 times during his life. The article points out, however, that the possibilities of being killed or seriously injured are very slight.

Of the 4.8 million residents of Massachusetts in 1953, less than 8 percent were involved in traffic accidents.

Of the 45,472 persons injured, 421 were fatally injured, 18,045 were seriously injured, and 27,006 were superficially injured. Injuries sustained in accidents caused 19,405 persons to lose an average of 19 days worktime per person; they hospitalized 6,647 persons for an average of 9.4 days each. Traffic accident injuries permanently reduced to some degree the ability of 2,117 persons to earn a living, and they similarly temporarily affected another 3,514 persons.

The total direct cost of traffic accidents in Massachusetts in 1953 was more than \$50 million, of which fatal injury accidents cost \$1.6 million; nonfatal injury accidents, \$28.7 million; and property-damage-only accidents, \$19.9 million.

This article points up one significant thing—of the total economic loss from traffic accidents, 59 percent was due to property damage alone, and 41 percent to injuries and related costs. The total direct cost of accidents was divided among six major elements: Property damage, \$27.6 million; treatment of injuries, \$3.4 million; worktime lost, \$4.5 million; loss of use of vehicle, \$0.4 million; legal and court fees, \$5.2 million; and awards and settlements, \$9.1 million.

The Economic Cost of Accidents in Relation to the Highway Systems (p. 39) evaluates the efficiency of the Massachusetts highway systems from the standpoint of economic losses through automobile accidents. A major finding was that of the 131,536 traffic accidents in Massachusetts during 1953, 87 percent occurred in urban areas. Likewise, 87 percent of the direct costs were from accidents occurring in urban areas.

Classified by highway systems, the cost of fatal accidents was \$662,810 on the Federal-aid primary system, \$227,480 on the Federal-

aid secondary system, and \$751,460 on local roads not a part of the Federal-aid systems.

In the Federal-aid primary system, State highways had a decidedly lower average accident rate than local roads. Conversely, in the Federal-aid secondary system the State highways had a much higher accident rate than local roads.

In addition to these general system findings, the article demonstrates that highways with full control of access experienced much lower accident rates, at a given traffic volume, than did those highways where access was not controlled.

The Economic Cost of Traffic Accidents in Relation to the Vehicle (page 44) compares the accident experience of passenger cars and trucks registered in Massachusetts. A further comparison is made of trucks grouped by visual classification and by gross weight classification.

A significant finding was that the cost of accidents per mile of travel for passenger cars was nearly double that of trucks, with the single exception of cost per mile for fatal accidents. It was also found that both the accident involvement rate and the accident cost per mile for passenger cars increased with the age of the car, but this was not true of trucks.

Truck-tractor-semitrailer combinations had the best accident record among the truck groups, on the basis of exposure, with the sole exception of a higher fatal involvement rate and fatal accident cost per mile. Panel and pickup trucks, together with the 2-axle, 6-tire trucks, accounted for 82 percent of the truck registrations, 73 percent of the truck travel, 74 percent of all truck involvements in accidents, and 80 percent of the truck accident costs.

An important relation developed with regard to registered gross weight was the decrease of accident cost per mile as the gross weight increased. Both the involvement rate and accident cost per mile of the heaviest group of trucks were the most favorable when compared to those of all other trucks.

The Economic Cost of Traffic Accidents in Relation to Highway Planning (p. 49) points up the value of traffic accident cost data to the highway planner in evaluating and scheduling highway improvement.

The article also compares the frequencies and costs of traffic accidents in 1955 with the results found in the 1953 Massachusetts study.¹ Despite dissimilarities in geographic characteristics and population densities, the relative distributions of accidents in the two States were quite consistent. As to costs, regardless of severity or type, accidents were more costly in Utah than in Massachusetts.

¹ The Economic Costs of Motor-Vehicle Accidents of Different Types, by Robie Dunham, PUBLIC ROADS, vol. 30, No. 2, June 1958. The basic data from that article are included in the tables on p. 50 of this issue.

The Economic Cost of Traffic Accidents in Relation to the Human Element

BY THE DIVISION OF TRAFFIC OPERATIONS
BUREAU OF PUBLIC ROADS

Reported by ¹ROBIE DUNMAN,
Transportation Economist

EXTENSIVE use of traffic accident cost data developed by the Massachusetts Department of Public Works and by the Massachusetts Registry of Motor Vehicles in cooperation with the U.S. Bureau of Public Roads was made in the Congressional report *The Federal Role in Highway Safety*.² These data have also been used as the basis of other reports relating economic costs to accident types, characteristics of the street and highway systems, and to the characteristics of motor vehicles. This article, using data from the same source, relates the economic cost of motor-vehicle traffic accidents to persons.

Comparisons involving passenger cars of Massachusetts registry in 1953 are made of the accident experience of automobile drivers, passengers, pedestrians, and other persons involved in motor-vehicle traffic accidents. The number of accidents, the number of persons involved, the number of persons injured fatally, seriously, and superficially, the number hospitalized, and the number permanently and temporarily disabled are discussed. Equally important, the cost of accidents and injuries is revealed.

Injury rates and injury cost rates, number of persons injured per 100,000 population, and the per capita cost of their injuries show the relative economic importance of the accidents and injuries experienced by each class of persons.

The Massachusetts study of the economic cost of motor-vehicle accidents encompassed the total driving experience of all licensed operators of passenger cars and cargo-carrying vehicles of Massachusetts registry, including those who experienced accidents and those who did not, in the operation of passenger cars during 1953, within or outside the State, and in the operation of cargo-carrying vehicles during 1955. However, the discussion in this article is confined to the accident experience of Massachusetts licensed passenger-car operators and persons in motor-vehicle traffic accidents involving passenger cars on public streets and highways of the State. This article excludes accident experience of truck operators, the number and cost of accidents occurring on private property, and the number and cost of mishaps involving acts of vandalism and acts of God.

Statistical studies of the motor-vehicle accident costs were based on a probability sample

designed to be accurate within 10 percent. To determine the number of persons involved in fatal accidents, original accident reports were reviewed and the number of persons reported represents a firm figure. The number of drivers involved in nonfatal injury and property-damage-only accidents was unavoidably slightly inflated because a driver who was involved in more than one accident during the year was counted as one driver each time he was involved in an accident. The number of passengers involved in accidents was estimated on the basis of an average passenger-car occupancy of 1.6 persons. The number of pedestrians and "other" persons nonfatally injured, however, was obtained from the original accident reports.

Costs reflected in this article are direct costs and consist exclusively of the money value of damage to property, injuries to persons, worktime lost, loss of use of vehicle, legal and court costs, damage awards in excess of actual cost, and small miscellaneous items. The number of persons losing worktime includes only those employed in gainful occupations. The number of workdays lost includes time lost for treatment of injuries, for convalescence, and for settlement of claims.

The activity class, "others," used throughout this article, consists of persons using conveyances other than motor-vehicles—such as bicycles, horsedrawn vehicles, and trolley cars.

Physical injury that impaired earning capacity is referred to as disability. The degree of disability as used is a measure of the extent

to which persons injured in motor-vehicle traffic accidents were handicapped in making a living. There are two classes of disability—temporary disability and permanent disability. Under the temporary disability class, there are two degrees of disability—total and partial. The degree of permanent disability is expressed in percentages of 25, 50, 75, and 100.

The data regarding persons permanently and temporarily disabled as a result of motor-vehicle traffic accidents in Massachusetts appeared to be incomplete and therefore not usable in this analysis. However, rather than include no information on this important part of the problem, an approximation was derived by applying to the number of persons injured in Massachusetts, the percentage of persons injured that were disabled in the State of Utah, where a similar study was being conducted.

Persons in Accidents

In 1953, the population of Massachusetts was 4,773,000. Of this total, 362,280 persons were involved in 131,536 motor-vehicle traffic accidents. Table 1 shows the number of accidents and their severity, the number of persons in accidents, the severity of their injuries, and their activity at the time of the accident.

The most significant point drawn from table 1 was the great number of persons involved and the relatively small number of persons killed and injured in motor-vehicle traffic accidents. The 362,280 persons involved in

Table 1.—Number of persons in traffic accidents involving passenger cars, classified by severity of accident and activity

Item of comparison	Severity of accident							
	Fatal		Nonfatal injury		Property-damage-only		All accidents	
	Number	Percent of total	Number	Percent of total	Number	Percent of total	Number	Percent of total
Involvements:								
Severity of injuries:								
Persons fatally injured.....	421	58.6	-----	-----	-----	-----	421	0.1
Persons nonfatally injured.....	168	23.4	44,883	47.9	-----	-----	45,051	12.4
Persons not injured.....	129	18.0	48,751	52.1	267,928	100.0	316,808	87.5
Total persons involved.....	718	100.0	93,634	100.0	267,928	100.0	362,280	100.0
Activity of persons:								
Drivers.....	344	47.9	54,260	57.9	167,455	62.5	222,059	61.3
Passengers.....	206	28.7	32,550	34.8	100,473	37.5	133,235	36.8
Pedestrians.....	158	22.0	5,735	6.1	-----	-----	5,893	1.6
Others.....	10	1.4	1,083	1.2	-----	-----	1,093	.3
Total persons involved.....	718	100.0	93,634	100.0	267,928	100.0	362,280	100.0
Accidents:								
Number of accidents.....	315	-----	33,270	-----	97,951	-----	131,536	-----
Persons per accident.....	2.3	-----	2.8	-----	2.7	-----	2.7	-----
Persons injured per accident.....	1.9	-----	1.3	-----	-----	-----	.3	-----

¹ Presented at the 39th Annual Meeting of the Highway Research Board, Washington, D.C., January 1960.

² House Document No. 93, 86th Congress, 1st Session, 1959.

motor-vehicle traffic accidents during 1953 represented one out of every 13 persons, or 7.6 percent of the total population. However, of all the persons involved in motor-vehicle traffic accidents only 45,472, or 12.5 percent, were either fatally or nonfatally injured. The vast majority of persons involved, 316,808 (87.5 percent), experienced no injury whatever.

In the distribution of persons involved in motor-vehicle traffic accidents by their activity at the time of accident, there were more drivers involved in accidents than there were persons in the other three activity classes combined. Of the total persons involved in accidents 61.3 percent were drivers, 36.8 percent were passengers, 1.6 percent were pedestrians, and 0.3 percent were others.

An interesting distribution, presented in figure 1, is the makeup of accidents of different severity. All persons in fatal injury accidents were not killed and all persons in nonfatal injury accidents were not injured. (For example, two cars, each with two occupants, may have collided. One occupant may have been fatally injured, another nonfatally injured, and the other two occupants may have avoided injury entirely.) Of the 718 persons involved in fatal injury accidents, 59 percent were killed, 23 percent were nonfatally injured, and 18 percent sustained no injuries whatever. Of the 93,634 persons involved in nonfatal injury accidents, 48 percent were injured and 52 percent were not injured.

In terms of number of accidents rather than involvement of persons, it may be noted from table 1 that of the 131,536 accidents reported 75 percent were property-damage-only accidents, and only 0.2 percent were fatal injury accidents.

Persons Injured and Injury Rates

In table 2 it is found that only 1 out of 8 persons involved in motor-vehicle accidents was injured and that more than half of those injured were not seriously injured. In terms of numbers, there were 421 persons fatally injured and 45,051 persons nonfatally injured. Of the persons nonfatally injured 27,006 experienced only superficial injuries such as mild shock, bumps, scratches, and bruises. The remaining 18,045 experienced serious injuries such as concussions, fractured bones, internal injuries, deep cuts, and dismemberment of body extremities.

Data from table 2 also indicate that more than 1 out of every 3 persons killed in traffic accidents was a pedestrian. It is significant, too, that more passengers than drivers were killed in traffic accidents, since on the basis of average car occupancy of 1.6 persons, the relative exposure of drivers as compared to that of passengers was in a ratio of 5 to 3. As to the number of persons nonfatally injured in traffic accidents, drivers constituted approximately one-half of the total.

In figure 2, the fatal injury rate—persons fatally injured in traffic accidents per 100,000 population—relates the high incidence of pedestrians and passengers in fatal accidents. Figure 3 shows the rate at which persons in

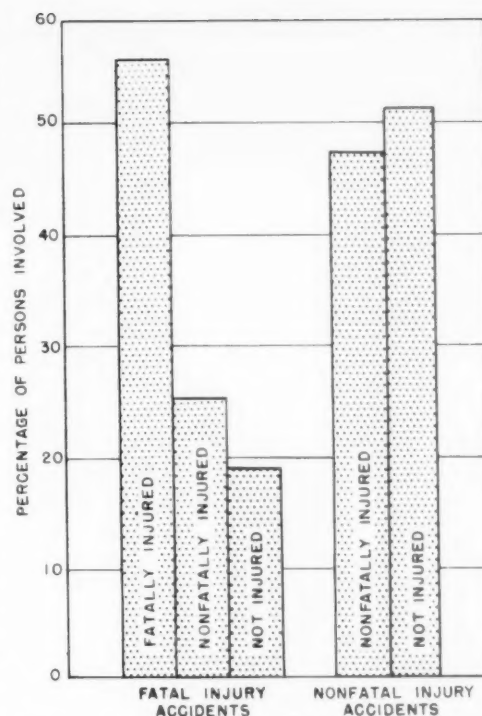


Figure 1.—Percentage distribution of persons involved in accidents, classified by severity of injury.

traffic accidents were seriously and superficially injured. This latter chart points up the superficial nature of the majority of traffic accident injuries and also shows that a much higher percentage of drivers were seriously injured than any other activity group. Furthermore, it shows that most pedestrians not fatally injured were only superficially injured.

Age and sex of persons injured

Table 3 shows the number of persons and the number per 100,000 population in each age and sex group that were injured in traffic accidents, classified by severity of injury. Of every 100,000 persons in the State, 953 were injured in a traffic accident during the year and the majority of those injured were male persons. A total of 25,579 males were fatally and nonfatally injured, or 1,107 males per 100,000 male persons.

Categorized by age groups, more persons from 30 to 39 years of age were injured than in any other age group, and the next largest

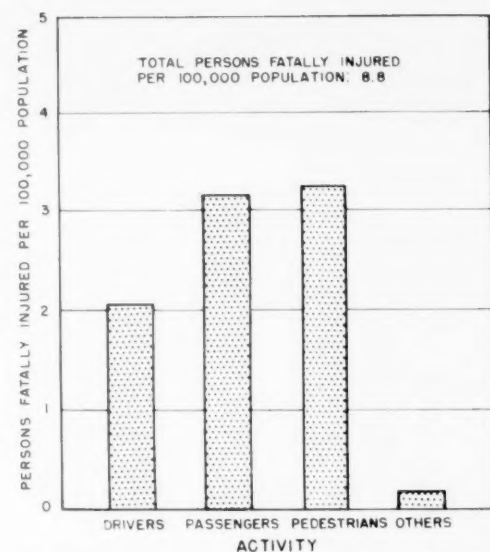


Figure 2.—Fatal injury rate, classified by activity.

category was the 20-29 age group. Of all persons injured 43 percent were in these two age groups. However, of more importance from the economic point of view, 70 percent of the persons injured were from 20 to 59 years of age—the ages supplying most of the labor force of the State.

In every age group except one, male persons had a higher fatal injury rate than females; and in the one exception the rate was the same for both sexes. In the 20-29 age group for males and in the 50 and over age groups for both males and females, a relatively high fatal injury rate occurred. The higher rates in the older age groups were believed to have been largely brought about by pedestrian deaths.

Turning to the nonfatal injuries per 100,000 in each age and sex group (table 3), males had a higher rate at every age, with only the youngest age group evidencing a closeness. Males in the 20-29 and 30-39 age groups had the highest injury rate, and females 60 and over had the lowest nonfatal injury rate.

Persons hospitalized

The number of persons nonfatally injured in traffic accidents that were hospitalized is shown in table 4. One of the most remarkable items derived from the 1953 Massachusetts accident study was evidence of the relatively

Table 2.—Number of persons in traffic accidents and number per 100,000 population, classified by severity and activity

Activity of persons	Persons injured				Total injured	Total not injured	Total involved in acci- dents
	Fatally	Nonfatally					
		Seriously	Super- ficially	Total			
Involvements:							
Drivers.....	102	12,800	9,434	22,234	22,336	199,723	222,059
Passengers.....	151	4,275	12,914	17,189	17,340	115,895	133,235
Pedestrians.....	158	770	3,775	4,545	4,703	1,190	5,893
Others.....	10	200	883	1,093	1,093		1,093
Total persons.....	421	18,045	27,006	45,051	45,472	316,808	362,280
Involvements per 100,000 popu- lation:							
Drivers.....	2.1	268	198	466	468	4,184	4,652
Passengers.....	3.2	89	271	360	363	2,428	2,791
Pedestrians.....	3.3	16	79	95	99	25	124
Others.....	.2	5	18	23	23		23
Total persons.....	8.8	378	566	944	953	6,637	7,590

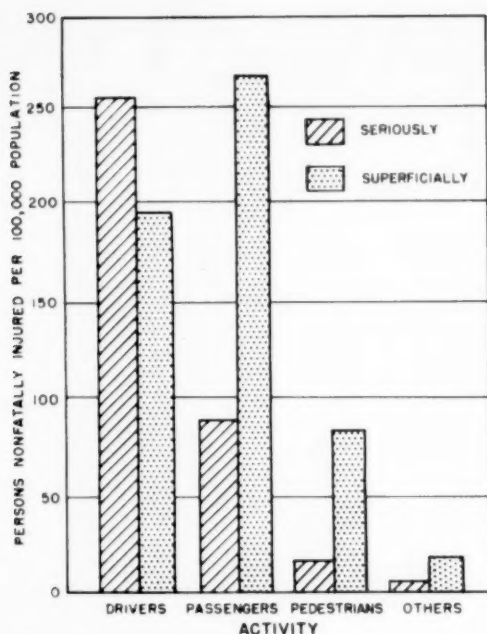


Figure 3.—Nonfatal injury rate, classified by activity and severity.

small number of nonfatally injured persons that required hospitalization. Only 15 percent of the persons nonfatally injured spent time in the hospital as a result of their injuries. Table 4 also shows that the 6,647 persons confined to the hospital remained there a total of 62,148 days or an average of 9.4 days per person.

During 1953, of the 45,051 persons nonfatally injured, 16,204, or 35.9 percent were examined in a hospital after the accident. Of those examined, 6,647 were confined while 9,557 persons were released from the hospital immediately after receiving emergency treatment. There were 28,847 persons, or 61.4 percent of all the persons nonfatally injured, that were either treated outside hospitals or received no professional treatment. These figures are additional evidence of the superficial nature of a large majority of traffic accident injuries.

Only 10 percent of the passengers that were injured required hospitalization, as compared with 16 percent of the drivers and 25 percent of the injured pedestrians. Persons in the

Table 3.—Number of persons injured in accidents and number injured per 100,000 population, classified by age, sex, and severity

Age of persons	Males injured			Females injured			All persons injured		
	Fatally	Nonfatally	Total	Fatally	Nonfatally	Total	Fatally	Nonfatally	Total
Number injured:									
Under 10...	25	2,903	3,018	12	2,238	2,250	37	5,231	5,268
10-19...	26	3,070	3,096	6	1,694	1,700	32	4,764	4,796
20-29...	59	5,187	5,246	13	4,542	4,555	72	9,729	9,801
30-39...	25	5,579	5,604	7	4,297	4,304	32	9,876	9,908
40-49...	22	3,668	3,690	6	2,741	2,747	28	6,409	6,437
50-59...	36	2,958	2,994	41	2,776	2,817	77	5,734	5,811
60 and over	75	1,856	1,931	68	1,452	1,520	143	3,308	3,451
Total...	268	25,311	25,579	153	19,740	19,893	421	45,051	45,472
Number per 100,000¹:									
Under 10...	5	653	658	3	510	513	4	583	587
10-19...	8	965	973	2	546	548	5	759	764
20-29...	19	1,673	1,692	4	1,402	1,406	11	1,535	1,546
30-39...	7	1,631	1,638	2	1,161	1,163	4	1,387	1,391
40-49...	7	1,207	1,214	2	818	820	4	1,003	1,007
50-59...	14	1,160	1,174	14	951	965	14	1,048	1,062
60 and over	23	575	598	17	369	386	20	462	482
Total...	12	1,095	1,107	6	801	807	9	944	953

¹ Number of persons injured per 100,000 in each age and sex group.

"other" category that were hospitalized had the highest percentage rate, but the number of persons in this category represented less than 3 percent of the total number of persons injured.

Considered by activity class, over one-half of the persons requiring hospitalization were drivers, one-fourth were passengers, and one-sixth were pedestrians.

Table 4.—Number of persons nonfatally injured in accidents and time in hospital as the result of such injuries

Activity	Total persons non-fatally injured	Persons hospitalized	Days in hospital	Average days in hospital
Drivers.....	22,234	3,624	33,804	9.3
Passengers...	17,189	1,630	15,020	9.2
Pedestrians...	4,545	1,115	10,580	9.5
Others.....	1,083	278	2,744	9.9
Total or average...	45,051	6,647	62,148	9.4

Worktime lost

The number of nonfatally injured persons losing worktime and the amount of worktime lost as a result of motor-vehicle traffic accidents, shown in table 5, revealed the interesting point that more than one-half of the persons injured did not lose time from work. This situation appeared to be brought about by two factors: First, many injured persons were not members of the labor force, and second, three-fifths of the nonfatal injuries were of a superficial nature. The average number of work days lost per person was 19 days.

Of the 22,234 drivers nonfatally injured, 60 percent lost time from work, whereas a similar comparison for passengers and pedestrians show percentages of 28 and 23, respectively. Of the 19,405 persons losing worktime, drivers accounted for 68 percent; passengers, 25 percent; pedestrians, 6 percent; and others, 1 percent.

Persons Disabled

Table 6 shows the number of persons injured in traffic accidents that were disabled, and the disability rate per 100,000 population. As

Table 5.—Number of persons nonfatally injured in accidents and worktime lost from such injuries

Activity	Total persons non-fatally injured	Persons losing worktime	Total work-days lost	Average work-days lost per person
Drivers.....	22,234	13,261	271,170	20.4
Passengers...	17,189	4,880	70,795	14.5
Pedestrians...	4,545	1,053	23,107	21.9
Others.....	1,083	211	4,200	20.0
Total or average...	45,051	19,405	369,272	19.0

mentioned earlier in this article, the distribution made according to degree of disability was based on percentage data provided by Utah. On this basis, of the 45,051 persons nonfatally injured in traffic accidents in Massachusetts, 2,117 were permanently disabled to some degree, and 3,514 were temporarily disabled either totally or partially. It is important to note that of all those persons nonfatally injured only 225 suffered total permanent disability, or a rate of less than 5 persons per 100,000 population.

Table 6 also indicates the relative importance of temporary and permanent disabilities in the overall traffic accident injury picture. Numerically, disabilities are relatively small but from an economic point of view they account for a sizeable portion of every accident direct cost dollar. Considering the permanently disabled, only a small proportion had total disability. In contrast, almost 65 percent of the permanently disabled group were in the 25-percent disability group.

Total Direct Cost of Accidents

The total direct cost of motor-vehicle traffic accidents is summarized in table 7 by severity of accident and by cost elements. In considering the direct cost of motor-vehicle accidents it is necessary to distinguish between property damage costs, which may occur in any type of accident, and property-damage-only accidents. Property damage relates to an element of cost of an accident whereas the property-damage-only accident refers to the severity class of an accident where no injuries were sustained. Total property damage costs of property-damage-only accidents amounted to \$17,900,000, which

Table 6.—Number of persons nonfatally injured and the extent of their disability

Degree of disability	Number of persons nonfatally injured ¹	Persons nonfatally injured per 100,000 population
Permanent disability:		
Total.....	225	4.7
75 percent.....	180	3.8
50 percent.....	360	7.5
25 percent.....	1,352	28.3
Subtotal.....	2,117	44.3
Temporary disability:		
Total.....	2,435	51.0
Partial.....	1,079	22.6
Subtotal.....	3,514	73.6
Total disabled.....	5,631	118.0
Total not disabled.....	39,420	826.0
Total injuries.....	45,051	944.0

¹ Distribution of persons according to degree of disability was derived from data provided by the State of Utah, where a similar accident cost study was conducted.

Table 7.—Total direct cost of traffic accidents by cost elements and severity of accident

Cost elements	Severity of accident				All accidents
	Fatal injury	Nonfatal injury	Total injury	Property-damage-only	
Property damage:	(\$1,000)	(\$1,000)	(\$1,000)	(\$1,000)	(\$1,000)
Vehicle.....	238	9,352	9,590	17,722	27,312
Other property.....	2	102	104	204	308
Subtotal.....	240	9,454	9,694	17,926	27,620
Injury treatment:					
Doctors and dentists.....	25	2,038	2,063	-----	2,063
Hospital.....	24	1,117	1,141	-----	1,141
Ambulance.....	2	56	58	-----	58
Miscellaneous.....	3	139	142	-----	142
Subtotal.....	54	3,350	3,404	-----	3,404
Incidental costs:					
Loss of vehicle use.....	6	105	111	248	359
Value of time lost.....	32	4,061	4,093	473	4,566
Legal assistance and court fees.....	293	4,338	4,631	558	5,189
Damage awards and settlements.....	1,017	7,380	8,397	689	9,086
Subtotal.....	1,348	15,884	17,232	1,968	19,200
Total.....	1,642	28,688	30,330	19,894	50,224

was almost twice the property damage costs of total injury accidents. This, however, was to be expected because of the much greater number of property-damage-only accidents. When all the other elements of costs were considered with the property damage costs, all injury accidents cost 52 percent more than the property-damage-only accidents.

The average accident cost dollar, illustrated in figure 4 for each severity class and for each of the elements of cost, vividly describes the makeup of the \$50,224,000 spent on accidents in Massachusetts during 1953. A most significant fact is that the cost of property damage was greater than that of all other elements of accident cost combined. The minor economic

role of the treatment of injuries as a cost element is also indicated.

The "fatal injury accident dollar" is representative of the \$1,642,000 spent on fatal accidents during 1953. It illustrates the overriding economic importance of damage awards and settlements, which in this instance largely represents the value of human life. The "fatal injury accident dollar" also shows that there is a fairly large element of property damage cost even in this most serious severity class of accident.

The "nonfatal injury accident dollar" represents the \$28,688,000 spent on nonfatal injury accidents during the 12-month period. In the breakdown of this cost dollar the work-time loss cost more than the treatment of injuries, and property damage accounted for one-third of the total cost of nonfatal injury accidents. Also, legal and court fees (15 cents out of the dollar) cost more than half as much as awards and settlements (26 cents out of the dollar).

The "property-damage-only accident dollar" is representative of the \$19,894,000 spent on property-damage-only accidents during the year. The significant thing about this diagram is that there were elements of cost other than property damage which accounted for 10 cents out of every property-damage-only accident dollar.

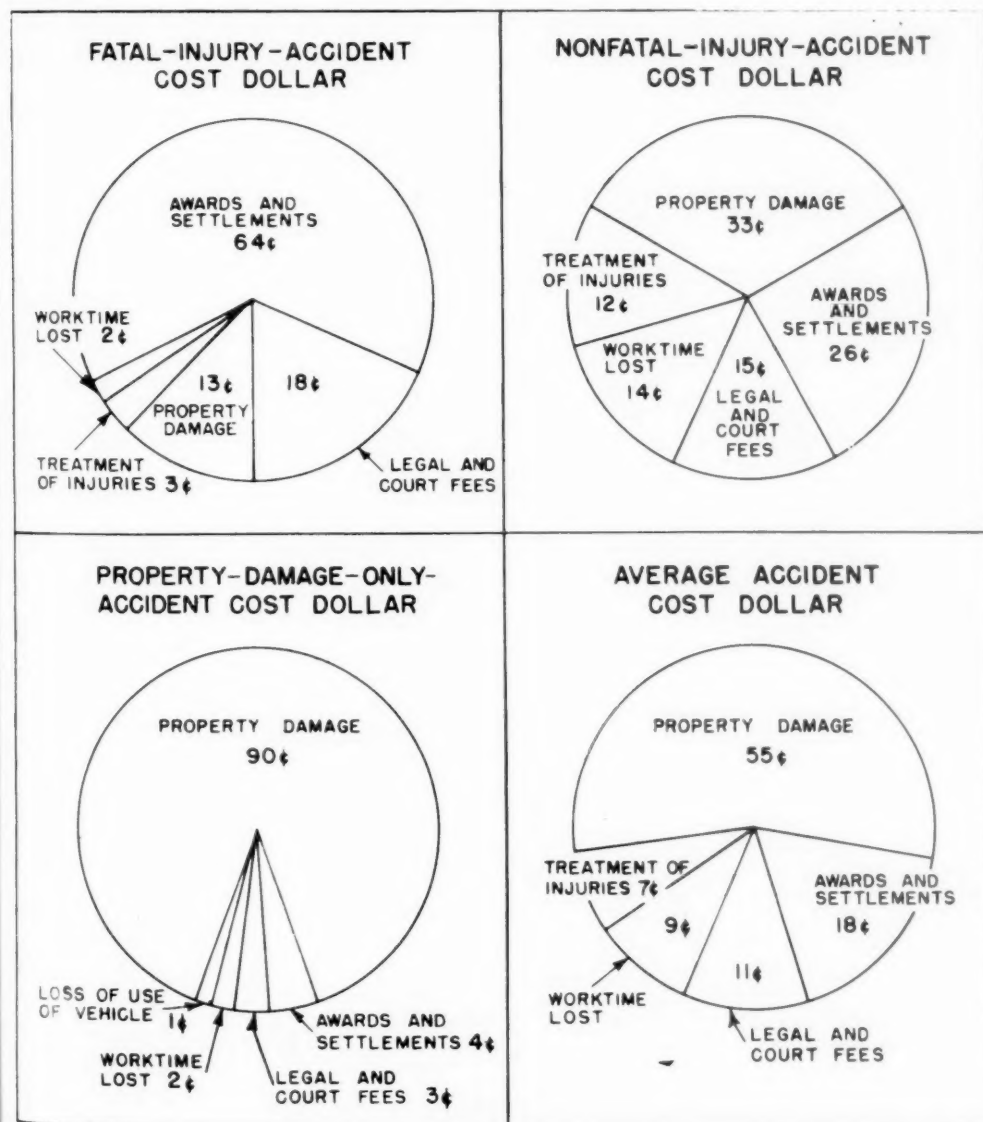


Figure 4.—Direct cost of traffic accidents shown as fractional parts of a dollar.

Table 8.—Direct cost of injuries by severity of injury and activity

Activity of persons injured	Fatally injured	Nonfatally injured ¹	All persons injured
	(\$1,000)	(\$1,000)	(\$1,000)
Drivers.....	156	11,552	11,708
Passengers.....	378	5,046	5,424
Pedestrians.....	824	2,305	3,129
Others.....	44	331	375
Total.....	1,402	19,234	20,636

¹ \$13,906,000—cost of seriously injured; \$5,328,000—cost of superficially injured.

Cost of injuries by activity

The direct cost to persons fatally and non-fatally injured in motor-vehicle traffic accidents is arrayed in table 8 by activity. The study did not provide a breakdown of costs for seriously and superficially injured persons according to their activity, but in total the amounts were \$13,906,000 and \$5,328,000, respectively. The \$20,636,000 cost of injuries is the total direct cost of fatal and nonfatal accidents, less the cost of property damage incurred in them, as shown in table 7.

Over half of the total traffic accident injury cost was borne by drivers, who experienced approximately twice as much injury cost as passengers. Average injury costs per person involved are calculated to be \$524 for drivers, \$313 for passengers, \$665 for pedestrians, and \$343 for all other injured persons.

The average direct cost of injuries sustained by persons in traffic accidents, classified by the severity of injury, is shown in figure 5. The average cost of a fatal injury was \$3,300, which was 4 times the amount expended for the serious nonfatal injury, and 17 times the cost for the superficial nonfatal injury. However, this comparison gives an erroneous idea of the economic importance of fatal injuries

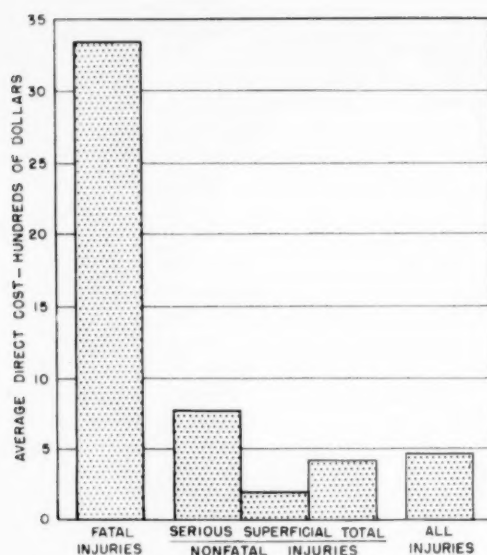


Figure 5.—Average direct cost of injuries sustained in accidents, according to severity of injury.

unless the total costs and number of persons are considered. The serious nonfatal injuries, in total, cost almost 10 times as much as fatal injuries. Referring back to table 2, there were 18,045 persons seriously injured, as compared to 421 persons fatally injured.

Cost of injuries by age and sex

Table 9 shows the direct cost of injuries to

persons in accidents by the severity of their injuries and by their age and sex. It also shows the injury cost rate per 100,000 population for the different groups. Among the important facts observed was that nonfatal injuries, \$403,000 per 100,000 persons, cost approximately 14 times as much as fatal injuries, \$29,000 per 100,000 persons; and that the cost of injuries to males exceeded the cost of injuries to females by 11.4 percent. In the injuries of males, the nonfatal cost was 10 times as great as the cost of their fatal injuries; while in the injuries of females, the nonfatal injury cost was 23 times as great as the cost of their fatal injuries.

The per capita cost of fatal injuries resulting from motor-vehicle traffic accidents, calculated by dividing injury cost by the number of persons (total population) in each age and sex group, shows that the age groups of 20-29 and over 50 had the highest injury cost rates. The high cost rate in the 20-29 year group would appear to reflect the high injury rate and the greater exposure to accidents of this age group. The extremely high rates for persons over 50 years of age reflects two things: increased earning power that comes with age and experience, and failing physical characteristics that come with age.

The per capita costs of nonfatal injuries resulting from traffic accidents are shown in figure 6, calculated in exactly the same way used for calculating the per capita cost of fatal injuries. The cost of injuries to males gener-

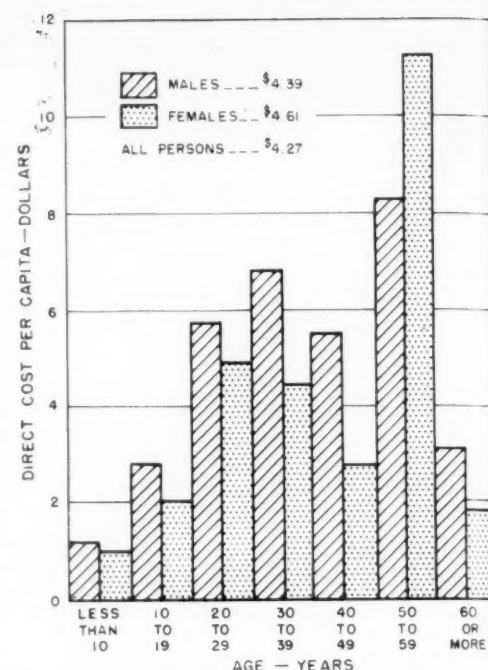


Figure 6.—Per capita direct cost, within each age and sex group, of nonfatal injuries.

ally increased with age—the 40-49 and the over 60 age groups being the only exceptions. The higher value of worktime lost and the slower rate of recovery in the 50-59 age group are clearly reflected in this chart.

Table 9.—Direct cost to persons injured in accidents and costs per 100,000 persons, classified by age, sex, and severity of injury

Age of persons	Males injured			Females injured			All persons injured		
	Fatally	Non-fatally	Total	Fatally	Non-fatally	Total	Fatally	Non-fatally	Total
Cost to persons injured:	(\$1,000)	(\$1,000)	(\$1,000)	(\$1,000)	(\$1,000)	(\$1,000)	(\$1,000)	(\$1,000)	(\$1,000)
Under 10.....	112	539	651	50	424	474	162	963	1,125
10-19.....	67	739	806	19	619	638	86	1,356	1,442
20-29.....	147	1,766	1,913	44	1,594	1,638	191	3,360	3,551
30-39.....	96	2,333	2,429	10	1,591	1,601	106	3,924	4,030
40-49.....	81	1,678	1,759	30	905	935	111	2,583	2,694
50-59.....	141	2,074	2,215	42	3,324	3,324	183	5,356	5,539
60 and over.....	370	1,009	1,379	193	683	876	563	1,692	2,255
Total.....	1,014	10,136	11,150	388	9,098	9,486	1,402	19,234	20,636
Cost to persons per 100,000: ¹									
Under 10.....	25	118	142	11	97	108	18	107	125
10-19.....	21	232	253	6	200	206	14	216	230
20-29.....	48	570	617	14	492	505	30	530	560
30-39.....	28	682	710	3	430	433	15	551	566
40-49.....	27	552	579	9	270	279	17	404	422
50-59.....	55	814	869	14	1,124	1,138	33	979	1,012
60 and over.....	115	312	427	49	174	223	79	236	315
Total.....	44	439	483	16	369	385	29	403	432

¹ Direct cost per 100,000 persons in each age and sex group.

The Economic Cost of Traffic Accidents in Relation to the Highway Systems

By **BERNARD B. TWOMBLY**,¹ Traffic Engineer,
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THE traffic accident toll in number of persons killed and injured has been publicized so frequently that many people are quite familiar with the figures and can even relate the details of the latest fatal accident. Few persons, however, have an intimate knowledge of where, on a statewide basis, most of the accidents are occurring, what types are most frequent, and what would be the odds, as measured in number of accidents per 100 million vehicle-miles, of having an accident on Massachusetts streets and highways. Prior to the 1954-55 accident cost study conducted by the Massachusetts Department of Public Works and the Registry of Motor Vehicles in cooperation with the U.S. Bureau of Public Roads, the monetary cost of traffic accidents was purely conjectural.

The purpose of this article is to evaluate the efficiency of the highway systems in Massachusetts from the standpoint of losses through automobile accidents. This article shows what the 1954-55 accident cost study revealed in terms of accident rates and direct costs of accidents on the State highways and local roads in Massachusetts and also points out where special attention should be directed in order to stem the tide of rising accident toll. It is reasonable to expect that the conditions which prevail in Massachusetts are typical of those in many other States.

Highway Systems in Massachusetts

The highway network in Massachusetts can be classified into six major systems whose total extent in 1953 was 24,506 miles. The three general systems consist of the Federal-aid primary system, Federal-aid secondary system, and non-Federal-aid (highways and roads not a part of any Federal-aid system). Within each system two classifications were made: State highways and local roads. A breakdown of total mileage and vehicle-miles traveled on each system during 1953, the year upon which the accident cost study was based, is shown in table 1.

Accident Experience on Highways and Roads

In 1953, there were 1.239 million registered passenger cars and 1.853 million licensed operators in Massachusetts. The vehicle-miles driven in passenger cars during 1953 on the State's highways totalled 11.628

billion. In the same year, there were 131,536 passenger-car accidents which resulted in a direct cost of \$50.224 million.

Massachusetts, though densely populated in many sections, still has a low proportion of urban areas when compared with rural areas. Approximately 15 percent of the 8,093 square miles are classed as urban and 85 percent as rural.

From table 2, the basic accident table, it is found that 88 percent of all accidents in the State occurred on urban highways and streets, which consisted of about one-fourth of the State's total mileage. This point is significant when considering density of accidents on the various highway systems. Moreover, two-thirds of all accidents in the State occurred in its 39 cities.

Table 2 also furnishes a comparison of the accident experience on the State highways and local roads. Without considering road mileage and traffic volumes, the 24,562 accidents on the State highways in comparison with the 106,974 accidents on the local road systems clearly show where the chief problem in accident reduction lies.

The Federal-aid primary and secondary systems accounted for 36 percent of the 131,536 accidents. Of the 47,681 accidents on these two systems, 24,080 occurred on State highways and 23,601 on local roads.

In terms of number of accidents classified by severity of accident, the property-damage-only accidents far outweighed the fatal and nonfatal injury accidents. Without the facts it is difficult to realize that 97,951 property-damage-only accidents occurred in one year and that these comprised 75 percent of all

accidents. Local systems accounted for 80 percent of the property-damage-only accidents.

Accident experience rates

The average number of accidents per mile of road on State highways was 11.6 as compared with 4.7 on local roads. The mileage of the State highways was 2,109 miles while mileage of the local roads was 22,397 miles. Thus, the frequency of accidents on State highways was more than double that on local roads, but the State highways constituted only 9 percent of the road mileage in the State.

In the comparisons of motor-vehicle traffic accident rates the efficiencies of the various systems with respect to safety are made evident. Table 3 shows accident rates per 100 million vehicle-miles and is of value since it employs the widely accepted method of comparing accident experience on highways.

The accident rates in table 3 are most revealing. The figures show the following comparisons in accident rates on each system: On the Federal-aid primary system the accident rate (per 100 million vehicle-miles) on the State highways was 432, and 1,211 on local roads. On the Federal-aid secondary system the rates were reversed, with 1,537 accidents per 100 million vehicle-miles on the State highways and 399 on local roads. On the non-Federal-aid highways and roads, with a preponderance of mileage on the local roads, there were 225 accidents per 100 million vehicle-miles on the State highways and 2,107 on local roads.

The reversal of accident rates in the various systems occasioned special study in an at-

Table 1.—System mileage and vehicle-miles traveled by passenger cars on State highways and local roads in Massachusetts in 1953

Highway system	Rural		Urban		Total	
	Miles	Million vehicle-miles	Miles	Million vehicle-miles	Miles	Million vehicle-miles
Federal-aid primary:						
State highways.....	1,119	2,124	397	1,904	1,516	4,028
Local roads.....	119	180	333	1,253	452	1,433
Subtotal.....	1,238	2,304	730	3,157	1,968	5,461
Federal-aid secondary:						
State highways.....	359	303	79	131	438	434
Local roads.....	1,301	762	447	801	1,748	1,563
Subtotal.....	1,660	1,065	526	932	2,186	1,997
Non-Federal-aid:						
State highways.....	141	166	14	48	155	214
Local roads.....	14,987	2,350	5,210	1,606	20,197	3,956
Subtotal.....	15,128	2,516	5,224	1,654	20,352	4,170
All highways and roads:						
State highways.....	1,619	2,593	490	2,083	2,109	4,676
Local roads.....	16,407	3,292	5,960	3,660	22,397	6,952
Total.....	18,026	5,885	6,450	5,743	24,506	11,628

¹ Presented at the 39th Annual Meeting of the Highway Research Board, Washington, D.C., January 1960.

Table 2.—Motor-vehicle traffic accidents by highway system and severity for passenger cars registered in Massachusetts, 1953

Highway system	Number of accidents, classified by severity and location											
	Fatal			Nonfatal			Property-damage-only			Total		
	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total
Federal-aid primary:												
State highways	40	33	73	1,903	2,249	4,152	4,481	8,703	13,184	6,424	10,985	17,409
Local roads	49	49	98	15	5,216	5,231	12,081	12,081	15	17,346	17,361	17,361
Subtotal	40	82	122	1,918	7,465	9,383	4,481	20,784	25,265	6,439	28,331	34,770
Federal-aid secondary:												
State highways	24	5	29	576	410	986	3,257	2,399	5,656	3,857	2,814	6,671
Local roads	20	20	40	30	1,514	1,544	4,676	4,676	30	6,210	6,240	6,240
Subtotal	24	25	49	606	1,924	2,530	3,257	7,075	10,332	3,887	9,024	12,911
Non-Federal-aid:												
State highways	26	118	144	120	19,933	20,053	90	272	362	210	272	482
Local roads	26	118	144	1,304	19,933	21,237	4,676	57,316	61,992	6,006	77,367	83,373
Subtotal	26	118	144	1,424	19,933	21,357	4,766	57,588	62,354	6,216	77,639	83,855
All highways and roads:												
State highways	64	38	102	2,599	2,659	5,258	7,828	11,374	19,202	10,491	14,071	24,562
Local roads	26	187	213	1,349	26,663	28,012	4,676	74,073	78,749	6,051	100,923	106,974
Total	90	225	315	3,948	29,322	33,270	12,504	85,447	97,951	16,542	114,994	131,536

Table 3.—Motor-vehicle traffic accident rate by highway system and severity for passenger cars registered in Massachusetts, 1953

Highway system	Number of accidents per 100 million vehicle-miles, classified by severity and location											
	Fatal			Nonfatal			Property-damage-only			Total		
	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total
Federal-aid primary:												
State highways	1.88	1.73	1.81	89.59	118.11	103.67	210.96	457.09	327.30	302.40	576.94	432.17
Local roads	3.91	3.41	3.66	8.33	416.28	365.03	964.16	843.05	8.33	1,384.35	1,211.51	1,211.51
Subtotal	1.73	2.59	2.23	83.24	236.45	171.81	194.48	658.34	462.64	279.42	897.40	636.67
Federal-aid secondary:												
State highways	7.92	3.81	6.68	190.09	312.97	227.18	1,074.91	1,831.29	1,303.22	1,273.26	2,148.09	1,537.32
Local roads	2.49	1.27	1.88	3.93	189.01	98.78	583.77	299.16	3.93	775.28	399.25	399.25
Subtotal	2.25	2.68	2.45	56.96	206.43	126.69	305.82	759.12	517.37	365.07	968.24	646.56
Non-Federal-aid:												
State highways	1.10	7.34	3.64	72.28	55.48	56.07	54.21	566.66	169.15	126.50	566.66	225.23
Local roads	1.03	7.13	3.45	55.48	1,241.15	536.83	198.97	3,568.86	1,567.03	255.57	4,817.37	2,107.50
Subtotal	1.03	7.13	3.45	56.59	1,205.13	512.15	189.42	3,481.74	1,495.29	247.05	4,694.01	2,010.91
All highways and roads:												
State highways	2.46	1.82	2.18	100.23	127.65	112.44	301.88	546.03	410.65	404.58	675.51	525.27
Local roads	.78	5.10	3.06	40.97	728.49	402.93	142.04	2,023.85	1,132.75	183.80	2,757.45	1,538.75
Total	1.52	3.91	2.70	67.08	510.56	286.11	212.47	1,487.84	842.37	281.08	2,002.33	1,131.20

tempt to determine the reasons therefor. Comparisons of the number of accidents per mile of highway and the number of accidents per 100 million vehicle-miles were both studied in relation to their respective system mileages. In neither of these possibilities could a definite indication or trend be detected.

There did appear to be a relationship between the number of accidents in terms of vehicle-miles as related to their average traffic volumes. However, this was not sufficiently pronounced to substantiate any definite conclusions as to the reasons for the variation of accident rates in the various highway systems. A possible explanation might be that the priority given, since World War II, to the construction of controlled-access highways on the Federal-aid primary system, and the financial assistance to local governments for the improvement of local roads on the Federal-aid secondary system, have brought about a reduction in the accident rates on those systems.

In any event, the results of the accident cost study point to the need for improvement of local roads on the Federal-aid primary system and State highways on the Federal-aid secondary system, and even greater emphasis should be given to non-Federal-aid local roads with their high accident totals, extensive mileages, and high rate of accidents per 100 million vehicle-miles.

Total Direct Cost of Accidents

The foregoing has been purposely confined to a discussion of accident experience and accident rates on the highway systems. This was done in order to promote a clearer understanding of the accident picture in Massachusetts. It is a fact, however, that an important and integral part of any motor-vehicle accident, and aside from the aspect of personal injury, suffering and inconvenience involved, is the monetary cost incurred.

In this article, dollar values will be confined to direct costs only. The cost of accidents in relation to the highway systems is shown in tables 4 and 5. For those who include among their responsibilities the improvement of accident-prone highways, the overall costs of accidents on the highway systems in table 4 are of special significance. The value of table 5 is that it brings into sharp focus the cost of an accident to the individual or individuals involved. The cost varied from \$203, for an average property-damage-only accident, up to \$5,499 for an average fatal accident in urban areas.

In 1953, there occurred a total of 131,536 accidents which involved \$50,224 million in direct costs. Fatal accidents made up 3 percent, nonfatal injury accidents 57 percent, and property-damage-only accidents 40 percent of the direct cost. In this cost breakdown it

is interesting to examine the cost comparisons in the light of what was previously found through accident rate comparisons by again using the highway systems. The costs and rates found below are derived from tables 3-5.

Federal-aid primary system

On the Federal-aid primary system, State highways had a better accident rate (per 100 million vehicle-miles of travel) than local roads in the ratio of 1 to 3. However, the

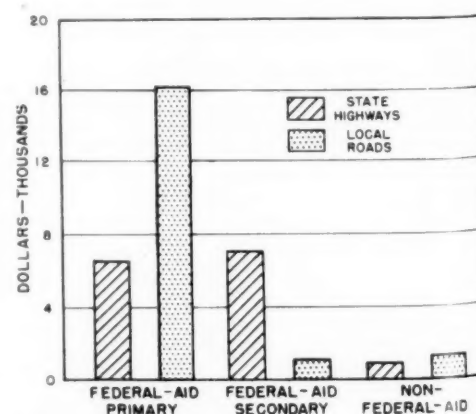


Figure 1.—Direct cost of traffic accidents per mile of highway in Massachusetts, classified by highway system.

State highway accident costs exceeded those on the local roads, being \$9.9 million and \$7.3 million, respectively.

The highest total costs in each subdivision of the Federal-aid primary system were those incurred in urban nonfatal accidents—that is, in accidents where nonfatal injuries were involved; they amounted to almost \$8.9 million. State highways and local roads each showed a total cost of approximately \$4.4 million. Also, nonfatal injury accidents in urban areas accounted for 52 percent of the total cost of all accidents on the Federal-aid primary system. While property-damage-only accidents were also very costly in total, in both rural and urban areas, these costs were only slightly more than half of the non-fatal total costs.

Federal-aid secondary system

On Federal-aid secondary highways the total accident cost was only 29 percent of the cost of accidents on the Federal-aid primary highways. Here again, the dissimilarity between accident rate comparisons and cost comparisons is worthy of note. In the Federal-aid secondary system local roads had a comparatively low accident rate and the State highways experienced a much greater rate, in the ratio of about 1 to 4. Nevertheless, the accident costs were in the ratio of only 2 to 3 on local roads versus State highways.

Another noteworthy fact is that property-damage-only costs were greater on the secondary system than were those of fatal and non-fatal injury accidents combined.

Non-Federal-aid highways

The non-Federal-aid highways and roads form the large network of local streets and connecting highways in Massachusetts. Compared with the highways and roads in the Federal-aid systems, they carry far less average daily traffic. The accident rate for the non-Federal-aid highways and roads, expressed in number of accidents per mile of roadway, was less than the Federal-aid highways and roads and yet, they accounted for 69 percent of all accidents and 56 percent of the total accident cost in 1953.

Of the \$28.0 million cost of accidents occurring on non-Federal-aid highways and roads, nonfatal injury accidents accounted for almost \$16.0 million, property-damage-only accidents accounted for \$11.3 million, and fatal accidents accounted for \$751,460. Of the total amount, a very large proportion, \$26.2 million, was incurred in urban areas. Thus, besides having a high accident rate in terms of accidents per 100 million vehicle-miles on its local road subdivision, accidents occurring on both non-Federal-aid State highways and local roads accounted for 56 percent of the cost of accidents in Massachusetts.

Economic Costs and Costs Rates

As previously noted, the efficiency of a highway in terms of accidents may be obtained by comparing accident rates. This is also true when comparing economic loss expressed in accident cost rates.

An analysis of figure 1, which shows the direct cost of accidents per mile of highway on each highway system, indicates that the highest accident cost per mile of highway, \$16,112, was on the Federal-aid primary local roads. The second highest cost was \$6,857 per mile on the Federal-aid secondary State highways and the third highest cost, \$6,537 per mile, was on the primary State highways. Accident costs per mile on the remaining highways and roads were minor in comparison to the above three. It should be stressed, however, that these costs are average costs only and that costs fluctuate greatly on the many types of roadways in each system. Accident costs per mile, of course, present only one side of the picture and do not reflect the volumes of traffic carried.

The comparison of accident costs per passenger-car-mile, excluding trucks, is shown in figure 2. The cost in dollars per 100 million vehicle-miles has been reduced to fractions of a cent per mile. On the whole, the State highways are costing the motorist an average of 0.28 cent per passenger-car-mile while on the local roads the accident cost per passenger-car-mile is 0.53 cent.

Table 4.—Direct costs of traffic accidents by highway system and severity for passenger cars registered in Massachusetts, 1953

Highway system	Cost of accidents, classified by severity and location											
	Fatal			Nonfatal			Property-damage-only			Total		
	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total
Federal-aid primary:												
State highways	\$214,420	\$179,750	\$394,170	\$1,920,530	\$4,428,550	\$6,349,080	\$1,189,790	\$1,976,520	\$3,166,310	\$3,324,710	\$6,584,820	\$9,909,530
Local roads	268,640	268,640	537,280	28,800	4,434,680	4,463,480	2,550,290	2,550,290	5,100,580	28,800	7,253,610	7,282,410
Subtotal	214,420	448,390	662,810	1,949,330	8,863,230	10,812,560	1,189,790	4,526,810	5,716,570	3,353,510	13,838,430	17,191,940
Federal-aid secondary:												
State highways	83,700	28,820	112,520	528,500	416,980	945,480	655,220	1,200,530	1,855,750	1,267,420	1,735,730	3,003,150
Local roads	115,560	115,560	231,120	4,500	950,410	954,910	962,920	962,920	1,925,840	4,500	2,028,890	2,033,390
Subtotal	83,700	143,780	227,480	533,000	1,367,390	1,900,390	655,220	2,253,450	2,908,670	1,271,920	3,764,620	5,036,540
Non-Federal-aid:												
State highways				134,400		134,400	5,430	19,910	25,340	139,830	19,910	159,740
Local roads	106,390	645,070	751,460	859,200	14,980,900	15,840,100	695,040	10,548,680	11,243,720	1,660,630	26,174,650	27,835,280
Subtotal	106,390	645,070	751,460	993,600	14,980,900	15,974,500	700,470	10,568,590	11,269,060	1,800,460	26,194,560	27,995,020
All highways and roads:												
State highways	298,120	207,970	506,090	2,583,430	4,845,530	7,428,960	1,850,410	3,286,960	5,137,370	4,731,960	8,340,460	13,072,420
Local roads	106,390	1,029,270	1,135,660	892,500	20,365,900	21,258,400	695,040	14,061,890	14,756,930	1,693,930	35,457,150	37,151,080
Total	404,510	1,237,240	1,641,750	3,475,930	25,211,520	28,687,450	2,545,450	17,348,850	19,894,300	6,425,890	43,797,610	50,223,500

Table 5.—Direct costs per traffic accident by highway system and severity for passenger cars registered in Massachusetts, 1953

Highway system	Cost per accident, classified by severity and location											
	Fatal			Nonfatal			Property-damage-only			Total		
	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total
Federal-aid primary:												
State highways	\$5.361	\$5.447	\$5.400	\$1,009	\$1,969	\$1,529	\$266	\$227	\$240	\$518	\$509	\$509
Local roads	5.482	5.482	5.482	1,920	850	1,335	211	211	211	1,920	418	419
Subtotal	5.361	5.468	5.433	1,016	1,187	1,152	266	218	226	521	488	494
Federal-aid secondary:												
State highways	3.488	5.644	3.859	918	1,017	959	201	538	344	329	617	450
Local roads	5.778	5.778	5.778	150	628	618	206	206	206	150	327	326
Subtotal	3.488	5.751	4.642	880	711	751	201	319	282	327	417	390
Non-Federal-aid:												
State highways				1,120		1,120	60	73	70	666	73	331
Local roads	4.092	5.467	5.218	659	752	746	149	184	181	276	338	334
Subtotal	4.092	5.467	5.218	698	752	746	149	184	181	280	337	334
All highways and roads:												
State highways	4.658	5.473	4.962	994	1,822	1,413	236	289	268	451	593	532
Local roads	4.092	5.504	5.332	692	7,639	7,759	149	190	187	280	351	347
Total	4.495	5.499	5.212	880	860	862	204	203	203	388	381	382

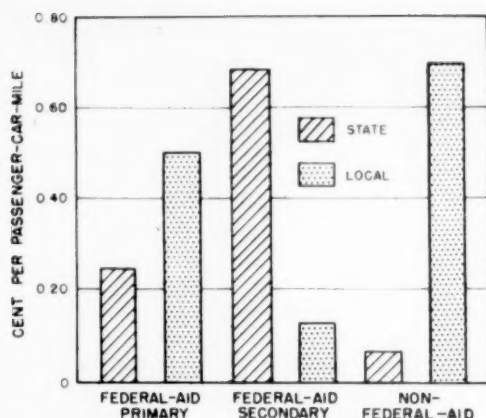


Figure 2.—Accident costs per passenger-car-mile on State highways and local roads in Massachusetts in hundredths of a cent.

Costs by type of accident

A breakdown of the number of accidents which occurred in Massachusetts in 1953 appears in table 6. Of the total accidents, 84 percent involved collisions of two or more motor vehicles, whereas 16 percent involved only one vehicle. In the former grouping, over 48 percent of the accidents were angle collisions. Rear-end collisions accounted for the next highest percentage, 20 percent, of the collisions with other vehicles. "Other" collisions, which included turning movements, parking maneuvers, and backing in traffic lanes, accounted for 12 percent of the collisions with other vehicles. Accidents involving only one motor vehicle included collisions with pedestrians, fixed objects, other objects (bicycles, scooters, etc.), and non-collision accidents.

By comparing the types of collisions on the State highways and local roads, it is interesting to note that rear-end collisions retained about the same proportion to the total collisions, 17 percent on State highways and 17 percent on local roads, but angle collisions were more prevalent on the local roads, 44 percent, whereas on State highways they accounted for only 23 percent of the accidents. Vehicle-pedestrian collisions accounted for only 2 percent of the collisions on State highways and 5 percent on local roads. Collisions with fixed objects were in about equal proportion, 6 percent on State highways and 5 percent on local roads.

The costs of the various types of accidents are shown in tables 7 and 8. Table 7 shows total costs and table 8 shows the accident cost rate per 100 million vehicle-miles of travel. The highest cost rate of accidents occurring on the State highways applied to head-on collisions. Rear-end and angle collisions had the next highest cost rates. On local roads the order of cost rates was angle collisions highest, rear-end second, and head-on collisions third.

Except for head-on collisions, sideswipe collisions involving two vehicles moving in opposite directions, single-car collisions with other objects, and non-collisions, the direct cost rates of accidents occurring on local roads were higher than the respective type of

Table 6.—Motor-vehicle traffic accidents by type of accident and highway system for passenger cars registered in Massachusetts, 1953

Type of accident	Federal-aid primary		Federal-aid secondary		Non-Federal-aid		All highways and roads		
	State highways	Local roads	State highways	Local roads	State highways	Local roads	State highways	Local roads	Total
Two or more car collisions:									
Head-on.....	2,306	1,462	631	514	15	7,751	2,952	9,727	12,679
Rear-end.....	3,403	3,395	864	1,273	15	13,363	4,282	18,031	22,313
Angle.....	4,367	7,726	1,276	2,000	15	34,484	5,658	47,210	52,868
Sideswipe (same direction).....	1,281	1,070	150	151	-----	4,397	1,431	5,618	7,049
Sideswipe (opposite direction).....	433	226	15	90	-----	708	448	1,024	1,472
Others.....	2,129	1,333	1,086	1,050	181	10,570	3,396	9,953	13,349
Total.....	13,919	15,212	4,022	5,078	226	71,273	18,167	91,563	109,730
One-car collision with:									
Pedestrians.....	201	327	248	283	30	4,759	479	5,369	5,848
Fixed objects.....	745	734	679	726	15	4,361	1,439	5,821	7,260
Other objects.....	1,751	875	1,146	153	181	2,358	3,078	3,386	6,464
Non-collision accidents.....	792	213	577	-----	30	622	1,399	835	2,234
Total.....	3,489	2,149	2,650	1,162	256	12,100	6,395	15,411	21,806
All accidents.....	17,408	17,361	6,672	6,240	482	83,373	24,562	106,974	131,536

collision on State highways. In total costs, only the sideswipe (opposite direction) and non-collision accidents had a greater cost on State highways.

In the Federal-aid primary system, reducing the cost rate of accidents per 100 million vehicle-miles to a cost rate per passenger-car-

mile, the total cost for all types of accidents on the State highways was 0.24 cent per passenger-car-mile while the local road cost rate was 0.50 cent per passenger-car-mile.

The highest cost rate for all types of accidents occurring on the Federal-aid secondary highways and roads was the rear-end col-

Table 7.—Direct costs of traffic accidents by type of accident and highway system for passenger cars registered in Massachusetts, 1953

Type of accident	Federal-aid primary		Federal-aid secondary		Non-Federal-aid		All highways and roads		
	State highways	Local roads	State highways	Local roads	State highways	Local roads	State highways	Local roads	Total
Two or more car collisions:									
Head-on.....	\$3,857,550	\$958,730	\$312,490	\$288,060	\$36,950	\$3,513,630	\$4,206,990	\$4,760,420	\$8,967,410
Rear-end.....	1,745,000	2,140,330	761,900	490,670	20,400	5,561,050	2,527,300	8,192,050	10,719,350
Angle.....	1,496,100	2,503,180	528,530	658,060	16,500	11,973,340	2,041,130	15,134,580	17,175,710
Sideswipe (same direction).....	487,980	221,920	83,310	39,640	-----	1,104,170	571,290	1,365,730	1,937,020
Sideswipe (opposite direction).....	339,850	97,100	43,500	33,040	-----	186,460	383,350	316,600	699,950
Others.....	452,570	293,600	465,170	186,600	5,430	912,600	923,170	1,392,800	2,315,970
Total.....	8,379,050	6,214,860	2,194,900	1,696,070	79,290	23,251,250	10,653,230	31,162,180	41,815,410
One-car collision with:									
Pedestrians.....	150,250	268,980	55,220	62,710	31,500	2,799,550	236,970	3,131,240	3,368,210
Fixed objects.....	547,850	670,290	225,310	145,710	35,400	1,395,380	808,560	2,211,380	3,019,940
Other objects.....	122,350	93,520	194,170	128,900	10,860	135,150	327,380	357,570	684,950
Non-collision accidents.....	710,030	34,760	333,550	-----	2,700	253,950	1,046,280	288,710	1,334,990
Total.....	1,530,480	1,067,550	808,250	337,320	80,460	4,584,030	2,419,190	5,988,900	8,408,090
All accidents.....	9,909,530	7,282,410	3,003,150	2,033,390	159,740	27,835,280	13,072,420	37,151,080	50,223,500

Table 8.—Direct costs of traffic accidents per 100 million vehicle-miles by highway system and type of accident for passenger cars registered in Massachusetts, 1953

Type of accident	Federal-aid primary		Federal-aid secondary		Non-Federal-aid		State highways	Local roads	Total
	State highways	Local roads	State highways	Local roads	State highways	Local roads			
Two or more car collisions:									
Head-on.....	\$95,768	\$96,904	\$72,002	\$18,430	\$17,266	\$88,818	\$89,970	\$68,476	\$77,119
Rear-end.....	43,322	149,390	175,553	31,393	9,533	140,573	54,048	117,837	92,186
Angle.....	37,142	174,681	121,781	42,102	7,710	302,663	43,651	217,701	147,710
Sideswipe (same direction).....	12,115	15,486	19,196	2,536	-----	27,911	12,218	19,645	16,638
Sideswipe (opposite direction).....	8,437	6,776	10,023	2,114	-----	4,713	8,198	4,554	6,020
Others.....	11,236	20,489	107,182	11,939	2,538	23,069	19,743	20,035	19,917
Total.....	208,020	433,696	505,737	108,514	37,047	587,747	227,828	448,248	359,610
One-car collision with:									
Pedestrians.....	3,730	18,770	12,723	4,012	14,720	70,767	5,068	45,041	28,966
Fixed objects.....	13,601	46,775	51,915	9,322	16,542	35,273	17,292	31,809	25,971
Other objects.....	3,038	6,526	44,740	8,247	5,075	3,416	7,001	5,143	5,891
Non-collision accidents.....	17,627	2,426	76,855	-----	1,261	6,419	22,375	4,153	11,181
Total.....	37,996	74,497	186,233	21,581	37,598	115,875	51,736	86,146	72,309
All accidents.....	246,016	508,193	691,970	130,095	74,645	703,622	279,564	534,394	431,919

lisions on State highways. Angle collisions, which had the highest cost rate on the system's local roads, had the second highest rate on the State highways. "Other" collisions had the third highest rate on State highways while on the local roads head-on collisions were third.

Accident cost rates for all types of accidents on the secondary system's State highways greatly exceeded the rate of costs on the local roads. In terms of cost per passenger-car-mile, all costs in the Federal-aid secondary system on State highways were 0.69 cent as compared with 0.13 cent on the local roads.

By type of accident, the highest costs per 100 million vehicle-miles on State highways not on any Federal-aid system were the head-on collisions, collisions with fixed objects, and pedestrian accidents. On the local roads the angle collisions accounted for 43 percent of the total direct cost of accidents occurring on these roads. The cost rate amounted to \$302,663 per 100 million vehicle-miles. This very high rate exceeded the rate for all other types of accidents occurring on any highway system by a wide margin. In comparing costs in each of the two highway classifications not a part of any Federal-aid system, it should be stressed that there were only 155 miles of State highways while there were 20,197 miles of local roads.

The cost per passenger-car-mile on the non-Federal-aid highways and roads was 0.07 cent on the State highways while the cost per passenger-car-mile on the local roads was 0.70 cent.

Costs on Selected Highways

In the analysis of the accident records and direct costs on the six highway systems, a general picture has been obtained on a State-wide basis. In order also to gain an impression of the costs on specific sections of highways it is of interest to consider the results of an accident cost study made in Massachusetts during 1957. This study was based on the accidents reported to the Registrar of Motor Vehicles in 1955. The purpose of the study was to determine the direct costs of accidents on two types of State highways; namely, those having no control of access and those on which access was controlled. Four highways were selected of the former type and they included a 2-, 3-, 4-, and 6-lane highway. Five highways of the latter type were selected and each were 4-lane divided highways which had been opened to traffic since June 1952. As part of the study, two curves, shown in figure 3, were prepared by plotting the yearly accident cost per mile against the average daily traffic volume for each of the nine sections of highway. The costs used were based on the results of the Massachusetts accident cost study and consisted of direct costs only. The results showed a yearly saving in cost of accidents per mile of highway of \$18,000 at 10,000 vehicles per day and \$68,000 at 25,000 vehicles per day on the controlled-access roads.

It is pointed out, however, that since this was an initial study, future research might alter the results obtained. Since this study

Table 9.—Accident rates and costs on State highways in Massachusetts comparing controlled-access highways and highways with no control of access, 1957

Sections of State highway	Miles studied	Average daily traffic	Severity of accidents				Accident rate ¹	Direct costs per mile
			Fatal	Nonfatal	Property-damage-only	Total		
Controlled access:								
Route 128 (Wellesley to Lynnfield).....	24.6	32,200	3	254	211	468	161.7	\$30,100
Route 15 (Sturbridge to Holland).....	6.7	15,700	2	26	17	45	117.2	13,900
Route 2 (Concord to Westminster).....	29.4	7,600	4	43	58	105	128.7	7,250
Route 1 (Danvers to Salisbury).....	21.6	15,500	5	86	68	159	130.1	14,800
Total.....	82.3	² 17,700	14	409	354	777	146.2	-----
Uncontrolled access:								
Route 1 (Revere to Peabody).....	7.8	30,900	3	213	109	325	370.5	79,700
Route 20-1 (Northboro to Weston).....	20.5	8,200	1	72	68	141	230.2	9,700
Route 20-2 (Northboro to Auburn).....	15.9	8,600	2	122	82	206	412.7	21,600
Route 9 (Brookline to Framingham).....	19.9	30,400	6	572	339	917	415.3	78,500
Total.....	64.1	² 17,900	12	979	598	1,589	378.4	-----

¹ Accidents per 100 million vehicle miles. ² Weighted average.

was completed, a new comparison of accident costs on eight of the nine highways has been made available and is included here in table 9. The accident data used in this table were those submitted in 1957. A comparison of the results in accident costs per mile with the curves on figure 3 proved to be of special interest since volumes on the highways had changed since 1955. On one highway section, Route 20-2, the so-called Southwest Connection, volumes

had decreased substantially because of the opening of the Massachusetts Turnpike. Despite this volume decrease, however, the yearly accident cost per mile was in close agreement with the curve in figure 3.

On the other highways, accident costs per mile were also quite consistent with the curves with only one notable exception. In the volume range above 25,000 average daily

(Continued on page 52)

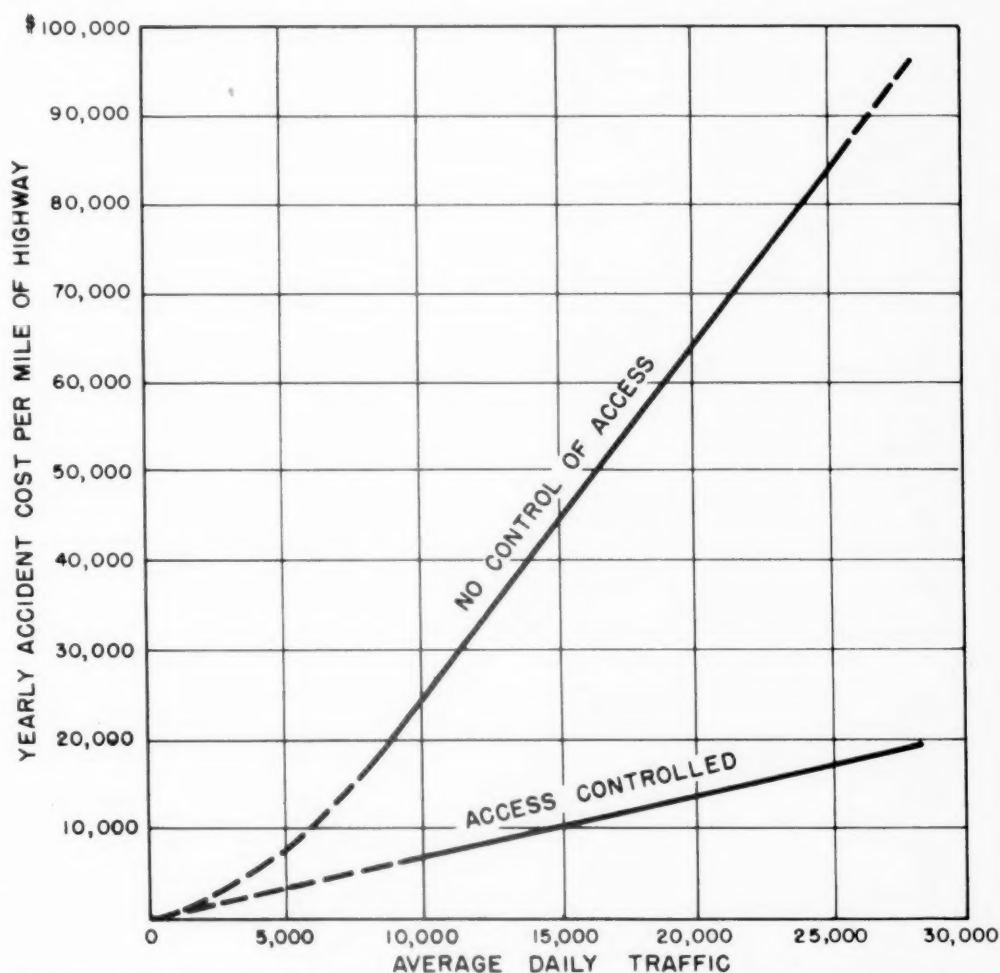


Figure 3.—Accident costs on Massachusetts highways with no control of access and with access controlled. Data based on 1955 accidents and traffic volumes.

The Economic Cost of Traffic Accidents in Relation to the Vehicle

BY THE DIVISION OF TRAFFIC OPERATIONS
BUREAU OF PUBLIC ROADS

THIS article discusses traffic accidents in Massachusetts and their resulting economic costs. The study applies only to vehicles of Massachusetts registry that were involved in traffic accidents within the State. The data for passenger cars are for the year 1953, and for trucks for the year 1955.

The purpose of this article is to present the cost of accidents in relation to the vehicle in a way that will aid those interested in pinpointing where prevention efforts should be centered, as well as those engaged in the economic analysis of highway improvements. The intent is not to fix responsibility for accidents by type of vehicle but rather to show what kinds of vehicles were involved and the extent of involvement in terms of cost.

Involvement and cost data are analyzed separately for passenger cars and trucks by age of vehicle and severity of accident. Further analyses are made of trucks involved in accidents and their direct costs in relation to the registered gross weight and type of truck. Comparisons are made throughout the article on the basis of the involvement per 100 million vehicle-miles of travel and the accident cost per vehicle-mile.

An involvement is one vehicle in one accident. For example, in the passenger car study, if a passenger car struck a pedestrian there was one involvement in one accident. If two passenger cars collided, there were two involvements in one accident. Also, in the passenger car study, if a passenger car collided with a truck this was one passenger car involvement in one accident. The truck involvement was not included in the passenger car study.

¹ Presented at the 39th Annual Meeting of the Highway Research Board, Washington, D.C., January 1960.

Table 1.—Number of motor vehicles registered in Massachusetts (passenger cars, 1953, and trucks, 1955) and their travel, classified by age of vehicle

	Age of passenger cars registered in 1953					Age of trucks registered in 1955				
	Under 2 years	2-4 years	4-8 years	8 years and over	Total	Under 2 years	2-4 years	4-8 years	8 years and over	Total
Number of vehicles	257,852	333,947	356,030	291,767	1,239,596	27,074	27,343	67,913	57,280	179,610
Percent of total	20.8	26.9	28.7	23.6	100.0	15.1	15.2	37.8	31.9	100.0
Vehicle travel:										
Total mileage (million miles)	3,331	3,390	3,143	1,764	11,628	355	396	795	495	2,041
Percent of total	28.6	29.2	27.0	15.2	100.0	17.4	19.4	39.0	24.2	100.0
Average annual travel (miles)	12,918	10,151	8,828	6,046	9,380	13,102	14,472	11,705	8,637	11,358

Overall Accident Experience

There were 1,239,596 passenger cars registered in Massachusetts during 1953 and 179,610 trucks registered in 1955. Table 1 shows that passenger cars traveled 11.6 billion vehicle-miles as compared to 2.0 billion vehicle-miles for trucks, or a ratio of about 6 to 1. The direct cost of passenger car accidents was \$50.2 million, whereas truck accident costs amounted to \$4.8 million. Thus, the cost attributable to trucks was about one-tenth of that for passenger cars.

In addition to the direct costs of traffic accidents just mentioned, there were other direct costs in connection with non-traffic accidents, traffic incidents, and non-traffic incidents that are not included in this article. Non-traffic accident involvements—accidents involving motion but not occurring on a public roadway—resulted in direct costs of \$2.7 million for passenger cars and \$327,000 for trucks. Traffic and non-traffic incidents—mishaps not involving motion and usually involving vandalism, fire, or acts of God—resulted in direct costs of \$4.7 million for passenger cars and \$865,000 for trucks. The present analysis is confined to the \$50.2 million for passenger cars and \$4.8 million for trucks which comprised the direct costs of motor-vehicle traffic accidents.

A comparison is made in figure 1 of the direct cost of traffic accidents on the basis of vehicle-miles of travel for passenger cars and trucks. It is immediately evident that trucks had an appreciably lower accident cost per mile of travel. In the case of all accidents, the truck cost per mile of travel was 0.23 cent, and the comparable cost for passenger cars was 0.43 cent. For nonfatal injury and property-damage-only accidents, the

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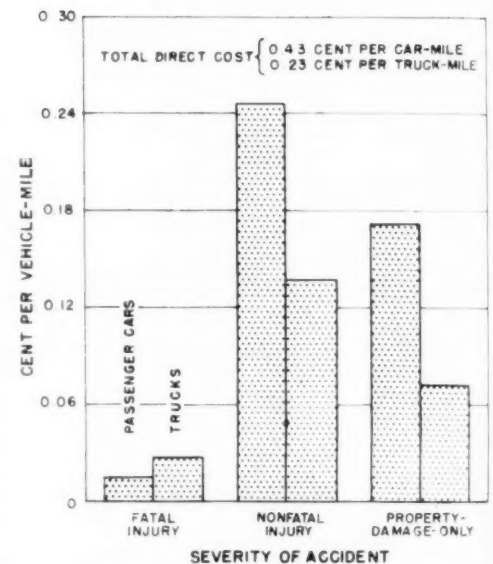


Figure 1.—Direct cost of traffic accidents in Massachusetts per passenger-car-mile of travel during 1953, and per truck-mile of travel during 1955, classified by severity of accident.

passenger car cost per mile was approximately double that of trucks. Only for fatal injury accidents was the rate for trucks higher, being 0.014 cent for passenger cars and 0.027 cent for trucks for each mile of vehicle operation.

From the data given in tables 2 and 3, a comparison can be made of the average cost per involvement of passenger cars and trucks. The high cost per involvement in fatal injury accidents—\$4,800 for passenger cars and \$6,800 for trucks—completely overshadows the cost per involvement of other types of accidents, but fatal injury accidents represented less than one-half of one percent of all accidents and only 3 percent of the total cost. The average cost for all involvements—\$226 for passenger cars and \$166 for trucks—was heavily influenced by the less costly property-damage-only involvements, which accounted for three-fourths of all accidents.

Age of Vehicles

The number of cars and trucks involved in accidents and the involvement rates by age of car and truck and severity of accident are summarized in table 2. For purposes of orientation on involvements and accidents,

Table 2.—Number of cars and trucks involved in traffic accidents, and the rate per 100 million vehicle-miles, classified by age and severity

Age of motor vehicle	Motor vehicles involved in—								Number of motor vehicles per 100 million vehicle-miles of travel involved in—			
	Fatal injury accidents		Nonfatal injury accidents		Property-damage-only accidents		All accidents		Fatal injury accidents	Nonfatal injury accidents	Property-damage-only accidents	All accidents
	Number	Percent of total	Number	Percent of total	Number	Percent of total	Number	Percent of total				
Passenger cars:												
Under 2 years.....	66	19.2	10,403	19.2	31,162	18.6	41,631	18.7	2.0	312	936	1,250
2-4 years.....	94	27.3	15,311	28.2	47,375	28.3	62,780	28.3	2.8	452	1,397	1,852
4-8 years.....	101	29.4	16,762	30.9	51,927	31.0	68,790	31.0	3.2	533	1,652	2,189
8 years and over.....	83	24.1	11,784	21.7	36,991	22.1	48,858	22.0	4.7	668	2,097	2,770
Total.....	344	100.0	54,260	100.0	167,455	100.0	222,059	100.0	3.0	467	1,440	1,910
Trucks:												
Under 2 years.....	19	23.2	705	15.6	4,080	16.9	4,804	16.7	5.4	200	1,150	1,355
2-4 years.....	13	15.9	959	21.3	4,749	19.6	5,721	19.9	3.3	242	1,200	1,466
4-8 years.....	28	34.1	1,881	41.7	9,395	38.8	11,304	39.2	3.5	237	1,182	1,442
8 years and over.....	22	26.8	964	21.4	5,981	24.7	6,967	24.2	4.4	195	1,209	1,408
Total.....	82	100.0	4,509	100.0	24,205	100.0	28,796	100.0	4.0	223	1,186	1,412

222,059 passenger cars were involved in 131,536 accidents in 1953. This total was comprised of 344 involvements in 315 fatal accidents, 54,260 involvements in 33,270 nonfatal injury accidents, and 167,455 involvements in 97,951 property-damage-only accidents.

In contrast, 28,796 trucks were involved in 27,041 accidents during 1955. Classified by severity there were 82 truck involvements in 77 fatal accidents, 4,509 involvements in 4,344 nonfatal injury accidents, and 24,205 involvements in 22,648 property-damage-only accidents. The ratio of truck involvements to accidents was almost 1.1 to 1 (28,796 to 27,041), whereas the corresponding ratio for passenger cars involved in accidents was 1.7 to 1 (222,059 to 131,536).

Accident involvement rates

When the age of passenger cars and trucks involved in accidents was compared, dissimilar results were found. The accident involvement rate of passenger cars, on the basis of involvements per 100 million vehicle-miles, increased steadily with age—passenger cars 8 years and older had an involvement rate of more than double that for cars under 2 years of age. This influence of age on the involvement rates can be construed as a strong argument for vehicle inspection even though there are contributory factors other than mechanical condition. With respect to accident involvement rates of trucks, there

was no apparent trend with age. Except for vehicles under 2 years of age, the involvement rate for passenger cars was higher than that for trucks. In the age group under 2 years, the truck rate exceeded the passenger car rate by only a narrow margin.

The influence of the age of the vehicle with respect to all accidents holds for each of the severity classes except for the fatal injury accidents. Throughout the article it will be seen that this class of accident severity has distinct characteristics in relation to nonfatal injury and property-damage-only accidents.

Just as for all accidents, the fatal involvement rate per 100 million vehicle-miles for passenger cars increased with age. When trucks under 2 years of age are ignored, the fatal involvement rate for trucks also increased with age. For vehicles less than 2 years of age, the fatal rate for trucks was almost 3 times that for passenger cars. For other than the newest vehicle group, the fatal involvement rates for passenger cars and trucks did not differ significantly.

Accident cost rates

The relationship between accident cost per million vehicle-miles and age of vehicle for each severity class of accident and for all accidents is shown in table 3 for passenger cars and trucks. A comparison of the costs for the two types of vehicles demonstrates the greater cost per mile of passenger car accidents. Although not as pronounced as the influence

of age on accident involvement rates, the cost per million vehicle-miles for passenger cars tended to increase with age for all accidents, for the fatal injury accident, and for the nonfatal injury accident. The cost per million vehicle-miles for property-damage-only accidents dropped off for the older vehicles for both passenger cars and trucks. This undoubtedly reflected the reduced value of the older vehicles involved.

The fact that the total direct cost of nonfatal injury accidents constituted almost 60 percent of the total cost of all accidents for both passenger cars and trucks has a great influence on the pattern of cost per million vehicle-miles for all accidents.

Visual Classification of Trucks

It was not practical to classify passenger cars by different body styles or weight. However, trucks were studied first by visual classification and second by registered weight. In the visual classification, trucks were grouped as follows: 2-axle, 4-tire panel and pickup trucks; all other 2-axle, 4-tire trucks; 2-axle, 6-tire trucks; 3-axle trucks; and truck-tractor-semitrailer combinations. The truck-tractor-semitrailer combinations, ranging from 3- to 5-axle units, were treated as a single classification. Truck and full trailer combinations are illegal in Massachusetts and therefore were not represented in the study.

Table 3.—Total direct cost of traffic accidents involving passenger cars and trucks, and the accident cost per million vehicle-miles, classified by age and severity

Age of motor vehicle	Accident costs								Accident costs per million vehicle-miles of travel			
	Fatal injury		Nonfatal injury		Property-damage-only		All accidents		Fatal injury	Nonfatal injury	Property-damage-only	All accidents
	Amount	Percent of total	Amount	Percent of total	Amount	Percent of total	Amount	Percent of total				
Passenger cars:												
Under 2 years.....	\$343,730	20.9	\$5,572,710	19.4	\$4,388,040	22.0	\$10,304,480	20.5	\$103	\$1,673	\$1,317	\$3,093
2-4 years.....	507,170	30.9	8,695,640	30.3	7,264,870	36.5	16,467,680	32.8	150	2,565	2,143	4,858
4-8 years.....	462,820	28.2	8,015,350	28.0	6,001,250	30.2	14,479,420	28.8	147	2,550	1,910	4,607
8 years and over.....	328,030	20.0	6,403,750	22.3	2,240,140	11.3	8,971,920	17.9	186	3,631	1,270	5,087
Total.....	1,641,750	100.0	28,687,450	100.0	19,894,300	100.0	50,223,500	100.0	141	2,467	1,711	4,319
Trucks:												
Under 2 years.....	136,700	24.5	266,300	9.6	290,560	20.1	693,560	14.5	385	751	819	1,955
2-4 years.....	81,820	14.6	541,170	19.6	273,330	18.9	896,320	18.8	207	1,368	691	2,265
4-8 years.....	206,370	36.9	1,526,680	55.1	612,510	42.4	2,345,560	49.1	260	1,920	771	2,951
8 years and over.....	133,950	24.0	435,020	15.7	269,180	18.6	838,150	17.6	271	879	544	1,694
Total.....	558,840	100.0	2,769,170	100.0	1,445,580	100.0	4,773,590	100.0	274	1,357	709	2,340

2-axle trucks

Table 4 contains the travel characteristics and accident involvement rates for trucks. During 1955 there were 179,610 trucks registered in Massachusetts. The largest single group was the 2-axle, 4-tire panel and pickup trucks, which accounted for 43 percent of the total truck population and 37 percent of the total truck-miles of travel. Of almost equal magnitude were the 2-axle, 6-tire single-unit trucks. Together these two groupings constituted over 82 percent of the total number of trucks and 73 percent of the mileage traveled by trucks. The combination units, although representing less than 6 percent of the number of trucks, accounted for almost 17 percent of the truck-miles traveled.

The second group of trucks, other 2-axle, 4-tire trucks, had a disproportionate share of the accident involvements and direct costs, considering the number registered and miles traveled by this class. They generally had the highest involvement and cost rates (tables 4 and 5) of any truck group. There were 18,350 trucks of this group registered in Massachusetts during 1955. This number represented 10 percent of the truck registrations and 8 percent of the truck mileage. On the other hand, this group had 12 percent of the accident involvements, and 11 percent of the direct costs.

The accident involvement rate per 100 million miles of travel for the "other" 2-axle, 4-tire trucks was 8.4 for fatal injury, 238 for nonfatal injury, and 1,867 for property-damage-only accidents. The involvement rate for this group in all accidents was 2,114, which was 50 percent greater than the average rate of 1,412 for all trucks. The fatal injury involvement rate was more than 3 times that of 2-axle, 4-tire panel and pickup trucks.

Figure 2 compares the accident cost per mile of travel by truck group and severity. The accident cost per mile for "other" 2-axle, 4-tire trucks was 0.05 cent for fatal injury, 0.19 cent for nonfatal injury, and 0.07 cent for property-damage-only accidents or a total cost of 0.31 cent per mile. The cost rate for the fatal injury accidents was more than 3 times the cost rate for panels and pickups and twice the average cost rate of 0.03 cent for fatal injury accidents for all trucks. The nonfatal injury rate for other 2-axle, 4-tire trucks was 40 percent greater than the average

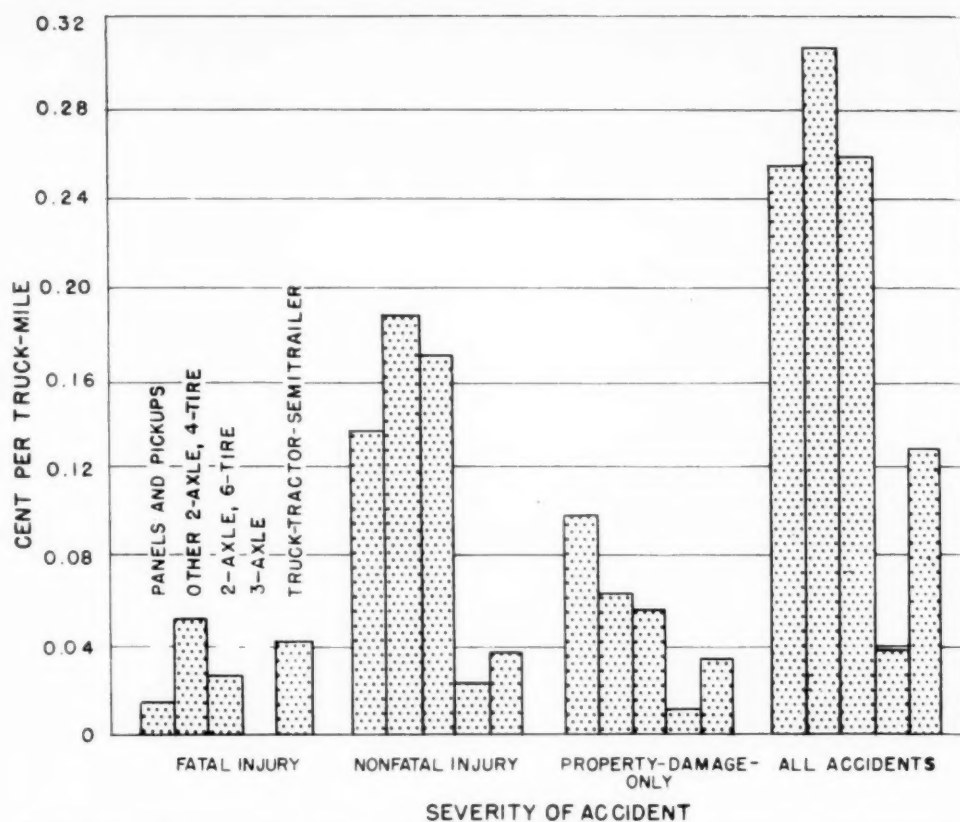


Figure 2.—Comparison of accident costs per mile of travel by visual classification of trucks and severity of accident.

nonfatal injury cost rate of 0.14 cent for all trucks. Only for property-damage-only accident involvements was the cost rate less than the average for all trucks. The total cost rate for this truck group was 32 percent greater than the average cost rate of 0.23 cent for all trucks. (The average cost rates for all trucks are shown in the totals in table 5.)

Panels and pickups and the 2-axle, 6-tire trucks appeared generally to have about the same accident involvement rate and cost per mile. For all accidents, the involvement rates were 1,444 and 1,430, respectively. In figure 2 the accident cost per mile of travel is shown to be 0.255 cent for panels and pickups and 0.259 cent for 2-axle, 6-tire trucks; these two groups of vehicles which constituted 82 percent of the total registrations accounted for 80 percent of the total direct cost of truck accidents.

Considering the fatal injury accidents, the involvement rate per 100 million truck-miles

for the panel and pickup trucks was 2.5 which was considerably less than the average rate of 4.0 for all trucks. The involvement rate for the 2-axle, 6-tire trucks in fatal accidents was 4.1 and was the third highest of the five vehicle types.

3-axle trucks

The fourth grouping of trucks, 3-axle trucks, consisted of less than 2 percent of all trucks registered and accounted for the same percentage of the total number of accidents. The total cost of accidents for this group was only 0.4 percent of the total cost of accidents for all trucks.

The number of 3-axle trucks involved in accidents per 100 million miles of travel was 992. Classified by severity, the involvement rate was 1.9 for 3-axle trucks in fatal injury accidents, 86 in nonfatal injury accidents, and 904 in the property-damage-only accidents. These involvement rates were, in general, the lowest rates for any of the five truck groupings

Table 4.—Number of trucks registered in Massachusetts during 1955, vehicle travel, involvement in accidents, and the accident involvement rate per 100 million truck-miles, by visual classifications and severity

Truck groups	Number of trucks	Vehicle travel		Trucks involved in—								Accident involvement rate per 100 million truck-miles			
		Total mileage (thousands)	Average annual mileage	Fatal injury accidents		Nonfatal injury accidents		Property-damage-only accidents		All accidents		Fatal injury	Nonfatal injury	Property-damage-only	All accidents
				Number	Percent of total	Number	Percent of total	Number	Percent of total	Number	Percent of total				
Single-unit trucks:															
Panel and pickup	77,180	758,139	9,823	19	23.2	1,982	43.9	8,946	36.9	10,947	38.0	2.5	261	1,180	1,444
Other 2-axle, 4-tire	18,350	165,866	9,039	14	17.1	395	8.8	3,097	12.8	3,506	12.2	8.4	238	1,867	2,114
2-axle, 6-tire	70,670	727,412	10,293	30	36.6	1,683	37.3	8,691	35.9	10,404	36.1	4.1	231	1,195	1,430
3-axle	3,220	52,206	16,213	1	1.2	45	1.0	472	2.0	518	1.8	1.9	86	904	992
Truck-tractor-semitrailer	10,190	336,473	33,020	18	21.9	404	9.0	2,969	12.4	3,421	11.9	5.3	120	891	1,017
Total	179,610	2,040,096	11,358	82	100.0	4,509	100.0	24,205	100.0	28,796	100.0	4.0	221	1,186	1,412

Table 5.—Total direct cost of traffic accidents involving trucks and the accident cost per million truck-miles, by visual classification and severity

Truck group	Accident costs								Accident cost per million truck-miles of travel			
	Fatal injury		Nonfatal injury		Property-damage-only		All accidents		Fatal injury	Nonfatal injury	Property-damage-only	All accidents
	Amount	Percent of total	Amount	Percent of total	Amount	Percent of total	Amount	Percent of total				
Single-unit trucks:												
Panel and pickup.....	\$114,510	20.5	\$1,050,880	37.9	\$767,860	53.1	\$1,933,250	40.5	\$151	\$1,386	\$1,013	\$2,550
Other 2-axle, 4-tire.....	88,320	15.8	315,710	11.4	107,340	7.4	511,370	10.7	532	1,903	647	3,083
2-axle, 6-tire.....	210,260	37.6	1,256,550	45.4	414,470	28.7	1,881,280	39.4	289	1,727	570	2,586
3-axle.....			13,410	0.5	6,360	0.5	19,770	0.4		257	122	379
Truck-tractor-semitrailer.....	145,750	26.1	132,620	4.8	149,550	10.3	427,920	9.0	433	394	444	1,272
Total.....	558,840	100.0	2,769,170	100.0	1,445,580	100.0	4,773,590	100.0	274	1,357	709	2,340

under consideration. Similarly, the cost in cents per mile (fig. 2) was the lowest for any of the five groups of trucks in all severity classes. These cent-per-mile rates were 0.03 cent for nonfatal injury, 0.01 cent for property-damage-only, and 0.04 cent for all accidents. There were no direct costs reported in connection with the single reported involvement in a fatal accident of a 3-axle truck.

Truck combinations

The data for the fifth truck group, the truck-tractor-semitrailer combinations (hereinafter referred to as combinations) offered a study of contrasts. Although only 5.7 percent of the total trucks registered, the combinations were responsible for 12 percent of all traffic accidents involving trucks, and 9 percent of the total direct cost. On the other hand, the combinations accounted for over 16 percent of the total truck travel, and their rates of involvement and cost per mile for all classes of severity except the fatal injury accidents were below the average values for all trucks.

The breakdown of the cost of accidents for combinations by severity class indicated that fatal injury accidents accounted for 34 percent, nonfatal injury accidents 31 percent, and property-damage-only accidents 35 percent of the total costs incurred. In contrast, considering the total direct cost for all truck accidents, fatal injury accidents accounted for less than 12 percent of the total cost and nonfatal injury accidents and property-damage-only accidents accounted for 58 percent and 30 percent, respectively.

Combinations had the second highest cost for fatal injury accidents. The average cost of a fatal injury accident for this truck group

was \$8,100 as compared to an average cost of \$6,450 for single-unit trucks. In addition to higher costs for fatal injury accidents, 1 out of every 190 combination involvements was fatal, whereas only 1 in every 409 involvements for single-unit trucks was fatal.

When viewed with consideration given to exposure in terms of truck-miles of travel, the higher percentages of truck combination involvements and costs are somewhat modified. The involvement rate for all accidents was 1,017 per 100 million miles of travel for combinations. Classified by severity this rate was 5.3 for fatal injury, 120 for nonfatal injury, and 891 for property-damage-only accident involvements per 100 million miles of travel. The cost of all accidents per mile of travel was 0.13 cent. By severity of accidents the cost rate was about the same, 0.04 cent for each class of severity.

From table 4 and figure 2 it appears that the truck combination involvement and cost rates were well below those of single-unit trucks for nonfatal injury and property-damage-only accidents. However, this was not so with regard to the fatal involvement and cost rates, as these rates for the truck combinations were considerably higher than the rates of single-unit trucks. The fatal involvement rate per 100 million miles was 5.3 for truck combinations, and 3.8 for all single-unit trucks. The cost of fatal accidents per mile of travel was 0.04 cent for the combinations compared to 0.02 cent for all single-unit trucks.

It becomes apparent from the foregoing discussion that any total view of trucks involved in accidents and their costs is predominantly weighted by the number of panel and

pickup trucks and 2-axle, 6-tire trucks, which dominated the total registrations, truck mileage, accident involvement, and cost rates. The combinations did play a rather important part in the total accident cost in relation to the number registered, but the large average annual mileage of this group tends to offset their disproportionate costs when viewed on an exposure basis.

Weight Classification of Trucks

The discussion up to this point has considered the relationship of truck and passenger car accident costs, and the variation of truck accident costs with age of vehicle and the visual classification of trucks. Another relationship of interest, particularly for economic analysis, is that which exists between accident costs and the weight classification of trucks—registered gross vehicle weights—as shown in table 6.

Of the 179,610 trucks registered during 1955 in Massachusetts, 56 percent had a gross vehicle weight under 8,500 pounds; 20 percent had weights between 8,500 and 16,500 pounds; 11 percent had weights between 16,500 and 24,500 pounds; 5 percent between 24,500 and 36,500 pounds; and 8 percent had gross weights of 36,500 pounds and over.

In addition to the registration data, table 6 indicates the truck travel for each registered gross vehicle weight group. It is important to note that the annual average mileage increased with registered weight. The increase between the last two weight groups is particularly significant. Trucks in the heaviest weight group traveled more miles in a year

Table 6.—Number of trucks registered in Massachusetts during 1955, vehicle travel, involvement in accidents, and the accident involvement rate per 100 million truck-miles, classified by gross weight and severity

Gross vehicle weight (pounds)	Number of trucks	Vehicle travel		Trucks involved in— ¹								Accident involvement rate per 100 million truck-miles			
		Total mileage (thousands)	Average annual mileage	Fatal injury accidents		Nonfatal injury accidents		Property-damage-only accidents		All accidents		Fatal injury	Nonfatal injury	Property-damage-only	All accidents
				Number	Percent of total	Number	Percent of total	Number	Percent of total	Number	Percent of total				
Under 8,500.....	100,940	949,636	9,408	41	50.0	2,662	59.1	11,001	45.5	13,704	47.6	4.3	280	1,158	1,443
8,500-16,500.....	36,340	333,960	9,190	13	15.8	722	16.0	4,998	20.6	5,733	19.9	3.9	216	1,497	1,717
16,500-24,500.....	19,050	224,139	11,766	7	8.5	416	9.2	3,289	13.6	3,712	12.9	3.1	186	1,467	1,656
24,500-36,500.....	9,540	132,633	13,900	4	4.9	245	5.4	2,084	8.6	2,333	8.1	3.0	185	1,572	1,759
36,500 and over.....	13,740	399,758	29,094	13	15.9	387	8.6	2,562	10.6	2,962	10.3	3.3	97	641	741
Total.....	179,610	2,040,096	11,358	82	100.0	4,509	100.0	24,205	100.0	28,796	100.0	4.0	221	1,186	1,412

¹ There were 352 trucks involved in accidents of which the weights were unknown. These included: 4 trucks involved in fatal accidents; 77 in nonfatal accidents; and 271 in property-damage-only accidents.

Table 7.—Total direct cost of traffic accidents involving trucks and the accident cost per million truck-miles, classified by gross weight and severity

Gross vehicle weight (pounds)	Accident costs								Accident cost per million truck-miles of travel			
	Fatal injury		Nonfatal injury		Property-damage-only		All accidents		Fatal injury	Nonfatal injury	Property damage-only	All accidents
	Amount	Percent of total	Amount	Percent of total	Amount	Percent of total	Amount	Percent of total				
Under 8,500.....	\$268,040	48.0	\$1,915,460	69.1	\$872,060	60.3	\$3,055,560	64.0	\$282	\$2,017	\$918	\$3,218
8,500-16,500.....	130,980	23.4	378,530	13.7	242,910	16.8	752,430	15.8	392	1,133	727	2,253
16,500-24,500.....	19,980	3.6	209,950	7.6	126,920	8.8	356,860	7.5	89	937	566	1,592
24,500-36,500.....	46,900	8.4	71,600	2.6	73,110	5.0	191,610	4.0	354	540	551	1,445
36,500 and over.....	78,310	14.0	143,270	5.2	122,160	8.5	343,740	7.2	196	358	306	860
Unknown.....	14,610	2.6	50,360	1.8	8,420	0.6	73,390	1.5	-----	-----	-----	-----
Total.....	558,840	100.0	2,769,170	100.0	1,445,580	100.0	4,773,590	100.0	274	1,357	709	2,340

in total than those in any other group except those registered under 8,500 pounds.

Light trucks have often been compared to passenger cars because of many similar vehicle characteristics. One of these similarities is average annual travel per vehicle. The average annual travel of passenger cars and light trucks was approximately equal. Passenger cars averaged 9,380 miles of travel annually and light trucks averaged 9,408 miles. By comparing the involvement rate of 1,910 per 100 million vehicle-miles for passenger cars with the involvement rate of 1,443 for light trucks it may be seen that passenger cars were involved in 32 percent more accidents on a mileage basis.

Table 6 also contains the accident involvements and the involvement rate per 100 million miles of travel for each gross weight group. Table 7 contains the accident costs and cost rate per million truck-miles of travel for each weight group. When the proportion of heavy trucks involved in accidents is compared with the proportion of heavy trucks in the total truck registrations, the comparison presents a somewhat unfavorable picture for heavy trucks. For example, trucks with a gross vehicle weight of 36,500 pounds and over represented less than 8 percent of the total trucks registered in Massachusetts and over 10 percent of the trucks involved in accidents. In terms of accident costs, however, the heaviest trucks accounted for only 7 percent of the total accident costs.

Accident involvement rates

The involvement rates for fatal injury accidents appeared generally to decrease with registered weight over the range covered by the first three groups and then tended to level off. The proportion of trucks in the heaviest group involved in fatal injury accident was high in comparison to the proportion of trucks in the other groups. This group had one vehicle in fatal accidents for every 30 vehicles in nonfatal accidents. On an exposure basis, the heaviest truck group had a favorable involvement rate of 3.3 per 100 million miles of travel, as compared to a rate of 4.0 for the remainder of the trucks.

In the case of nonfatal injury accidents, the involvement rates decreased with regis-

tered weight. However, for the property-damage-only accidents the tendency was for an increase with weight excepting the heaviest group vehicles. For these trucks, 36,500 pounds and over, the rate dropped off sharply to less than half that for the other weight groups combined.

The involvement rate for all accidents, regardless of severity, was 741 for the heaviest trucks and 1,554 for all other trucks.

Accident cost rates

Accident cost rates per mile of travel are shown in figure 3. The heaviest trucks had the most favorable cost rates among the weight groups. For nonfatal injury accidents the cost rate of 0.04 cent per mile for the heaviest trucks was about one-fourth of the

cost rate of 0.16 for all other trucks in accidents of comparable severity. The property-damage-only cost rate was 0.03 cent per mile for the heaviest trucks and 0.08 for all other trucks. The cost rate for all accidents was 0.09 cent per mile for the heaviest trucks, which was one-third of the cost rate of 0.27 cent for all other trucks.

A most significant finding of the report is the very definite decrease of accident cost per mile of travel with increase of registered gross vehicle weight. This is the first time such data have become available. With reference to the results for all accidents the cost rate ranges from 0.32 cent per mile for the lightest group to 0.09 cent per mile for the heaviest group of trucks.

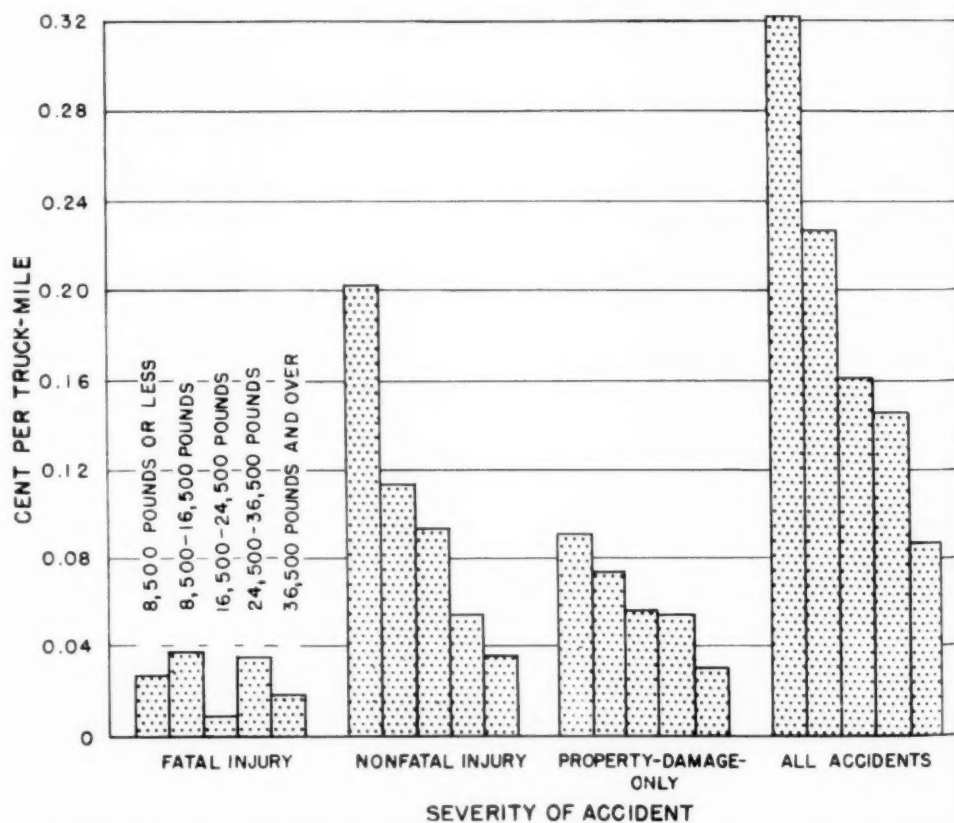


Figure 3.—Comparison of accident costs per mile of travel by gross vehicle weight and severity of accident.

The Economic Cost of Traffic Accidents in Relation to Highway Planning

and a Comparison of Accident Costs in Utah and Massachusetts

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of Highways for Planning,
Utah State Department of Highways¹

TODAY, highway planners are seeking more scientific methods of evaluating existing highways and designing and programming new facilities. The highway administrator and planner realize as never before the importance of engineering tools that will permit them to schedule construction on the basis of need, allocate highway funds on a priority basis, select additions to the highway systems, change system classifications, select proper alternate routes or locations, and to cope effectively with public and private groups having vested interests in the processes of planning and programming.

Some States have employed sufficiency ratings to assist them in accomplishing these objectives. This method simply assigns a point rating to each section of road according to its ability to provide traffic service in a safe and efficient manner. Other States have employed economic analyses using factors such as highway costs, revenues, and benefits. In the main, this approach has been simplified to include only the benefit quotient which reflects primarily a savings to the motor-vehicle user in operating cost and time through improved alignment. Some States use both approaches.

In the methods generally in use, one important factor is too often omitted—traffic accident rates. Some States incorporate accident rates in their sufficiency ratings, but more do not. It is known that sections of highway having a good adequacy rating, as provided by the sufficiency rating system, sometimes may have a high traffic accident frequency.

Traffic accident rates normally are not included in economic analyses of the cost-benefit variety at all. The principal reason for the omission has been the unreliability of traffic accident data. Too many accidents are not reported; and for those that are, the reports often do not clearly indicate where the accidents occurred. But one of the greatest deterrents has been the lack of information on accident costs related to the types of vehicles, classes of highways, roadway features, types of accidents, and severity of accidents.

Application of Accident Cost Factor

Traffic accident data should be one of the highway planner's most important tools to justify street and highway improvements. Just to illustrate this point, a traffic accident study was made on State Street in Salt Lake City. The study section, 17 blocks in length, carried over 30,000 vehicles daily. During a 3-year period, more than 1,000 traffic accidents occurred on this street, and over 700 of them took place at intersections. The street is a 6-lane divided roadway with parallel parking on each side.

It is estimated that had this traffic been carried on a street of freeway design, slightly more than 200 accidents would have been expected instead of 1,000. An Interstate System improvement is being planned to parallel State Street, and the portion paralleling the 17-block study section is expected to carry 100,000 vehicles daily by 1975.

According to the Utah accident cost study, the direct cost for passenger-car accidents occurring on major urban arteries was 0.49 cent per vehicle-mile. Using Utah study data, it was estimated that the direct cost of accidents on the Interstate System would be only 0.13 cent per freeway vehicle-mile. Thus, there would be a savings in accident costs of 0.36 cent per vehicle-mile on streets of freeway design. Based on an estimated traffic volume of 100,000 vehicles daily by 1975, the savings in accident costs would approach \$330,000 annually.

The significant point is that an accident cost savings of such magnitude should not be overlooked in justifying an investment of \$20 million, as would be required in constructing a freeway parallel to State Street. Furthermore, the savings figure is on the conservative side because it does not include indirect costs relating to traffic accidents.

In this analysis, the reduction in traffic accidents on freeways was based upon the California study² which indicated that there were five times fewer accidents on their freeways than on local streets. In addition, in the analysis, the accidents expected on the

freeway were distributed as to type in accordance with those happening on the Detroit Expressway. This was done in order to isolate those types of accidents that could not occur on a freeway.

Utah and Massachusetts Results Compared

The Utah State Road Commission has completed a study of the passenger-car phase of traffic accident costs. It was based upon passenger cars registered by the Utah State Motor Vehicle License Bureau in 1955. A sample was selected from the registration list, a universe of 268,000 passenger cars. The registration sample was deemed to be of sufficient size to satisfactorily approximate the general accident experience of the motoring public, but in order to obtain more detailed information on fatal and nonfatal injury accidents the State's accident files were sampled at a much higher rate than the registration list.

Only a small portion of the data collected in the Utah accident cost study is reported here, in tables 1-4, to provide a comparison of the number of traffic accidents and their costs in Utah and Massachusetts.³ When comparing the values for the two States, it must be kept in mind that the base year of the Utah study was 1955, and for the Massachusetts study it was 1953. Since only a two-year difference was involved, no attempt was made to adjust the data to a common year.

The size of Utah is 82,346 square miles, whereas in Massachusetts the area is 7,867 square miles. In 1955, Utah had a population of 797,000; there were 268,000 registered passenger cars, 455,000 licensed drivers, 31,400 miles of highways and streets, and 2,523 million vehicle-miles of travel. During 1953, there were 4,773,000 persons living in Massachusetts, 1,239,000 registered passenger cars, 1,858,000 licensed drivers, 24,500 miles of highways and streets, and 11,628 million vehicle-miles of travel.

³ A discussion of the Massachusetts data may be found in the article *The Economic Costs of Motor-Vehicle Accidents of Different Types*, by Robie Dunman, *PUBLIC ROADS*, vol. 30, No. 2, June 1958.

¹ Presented at the 39th annual meeting of the Highway Research Board, Washington, D.C., January 1960.

² *The Economy of Freeways*, by Lloyd Aldrich. City of Los Angeles, Street and Parkway Design Division, June 1953.

Table 1.—Comparison of the number of motor-vehicle traffic accidents involving passenger cars in Utah during 1955 and in Massachusetts during 1953

Item of comparison	Number of accidents		Percent of total		Number of residents per accident		Number of registered passenger cars per accident		Number of licensed operators per accident		Number of accidents per 100 million vehicle-miles of travel	
	Utah	Mass.	Utah	Mass.	Utah	Mass.	Utah	Mass.	Utah	Mass.	Utah	Mass.
Severity of accident:												
Fatal injury.....	77	315	0.2	0.2	10,350	15,152	3,481	3,933	5,909	5,598	3.1	2.7
Nonfatal injury.....	9,048	33,270	19.0	25.3	88	143	30	37	50	56	359	286
Property-damage-only.....	38,453	97,951	80.8	74.5	21	49	7	13	12	19	1,524	842
All accidents.....	47,578	131,536	100.0	100.0	17	36	6	9	10	14	1,886	1,131
Type of accident:												
Passenger-car collision with—												
Other motor vehicles.....	29,044	109,730	61.0	83.4	27	44	9	11	16	17	1,151	943
Pedestrians.....	1,792	5,848	3.8	4.5	445	809	150	210	254	315	71	51
Fixed objects.....	7,741	7,260	1.5	5.5	1,076	654	362	170	614	255	29	63
Other objects.....	11,921	6,464	25.1	4.9	67	746	22	194	38	290	473	55
Non-collision accidents.....	4,080	2,234	8.6	1.7	195	2,170	66	563	112	845	162	19
All accidents.....	47,578	131,536	100.0	100.0	17	36	6	9	10	14	1,886	1,131

Table 2.—Comparison of direct costs of motor-vehicle traffic accidents involving passenger cars in Utah during 1955 and in Massachusetts during 1953

Item of comparison	Total direct cost		Percent of total		Total direct cost											
					Per accident		Per capita		Per passenger car registered		Per licensed operator		Per mile of road		Per 100 million vehicle-miles of travel	
	Utah	Mass.	Utah	Mass.	Utah	Mass.	Utah	Mass.	Utah	Mass.	Utah	Mass.	Utah	Mass.	Utah	Mass.
Severity of accident:	(\$1,000)	(\$1,000)													(\$1,000)	(\$1,000)
Fatal injury.....	284	1,642	1.2	3.3	\$3,690	\$5,213	\$0.36	\$0.34	\$1.06	\$1.32	\$0.62	\$0.88	\$9	\$67	11	14
Nonfatal injury.....	11,559	28,688	49.5	57.1	1,277	862	14.50	6.01	43.13	23.15	25.40	15.44	368	1,171	458	247
Property-damage-only.....	11,506	19,894	49.3	39.6	299	203	14.44	4.17	42.93	16.06	25.29	10.71	366	812	456	171
All accidents.....	23,349	50,224	100.0	100.0	491	382	29.30	10.52	87.12	40.53	51.31	27.03	743	2,050	925	432
Type of accident:																
Passenger-car collision with—																
Other motor vehicles.....	17,401	41,816	74.5	83.3	599	381	21.83	8.76	64.93	33.75	38.24	22.50	554	1,707	690	390
Pedestrians.....	1,417	3,375	6.1	6.7	791	572	1.78	.71	5.29	2.72	3.11	1.82	45	138	56	29
Fixed objects.....	271	3,023	1.2	6.0	366	414	.34	.63	1.01	2.44	.60	1.63	8	123	11	26
Other objects.....	1,880	673	8.0	1.3	158	105	2.36	.14	7.01	.54	4.13	.36	60	27	74	6
Non-collision accidents.....	2,380	1,337	10.2	2.7	583	608	2.99	.28	8.88	1.08	5.23	.72	76	55	94	11
All accidents.....	23,349	50,224	100.0	100.0	491	382	29.30	10.52	87.12	40.53	51.31	27.03	743	2,050	925	432

In comparing the accident rates and costs for the two States, it is quite evident that the results were influenced by such factors as population density, travel speeds, urban characteristics, etc. It is likely that many of the differences could be explained, but to interpret the accident experience of States so widely separated geographically and having such dissimilar characteristics is beyond the scope of this article. Population density alone would be a major factor to consider in any analysis of traffic accidents. In Massachusetts there were 596 persons per square mile, as compared with 10 in Utah.

In spite of the dissimilarities of the two States, however, there is remarkable consistency in the relative distribution of accidents when classified according to severity and type. The most common method of comparison is to express the number of accidents and their costs in terms of 100 million vehicle-miles of travel. This is done in the last two columns of the tables. In general, accidents were costlier in Utah than in Massachusetts, regardless of severity or type of accident or type of collision.

An attempt to draw conclusions on the basis of the data presented here for two strikingly different States would not be justified, but certainly the results add significantly to the knowledge needed to develop national trends of traffic accidents.

Table 3.—Comparison of the number of collisions between passenger cars or passenger cars and other motor vehicles in Utah during 1955 and Massachusetts during 1953, classified by type of collision

Type of collision	Number of collisions		Percent of total		Number per 100 million vehicle-miles of travel	
	Utah	Mass.	Utah	Mass.	Utah	Mass.
Angle.....	9,911	53,320	34.1	48.6	393	458
Rear-end.....	10,580	22,501	36.4	20.5	419	193
Head-on.....	1,117	12,789	3.9	11.6	44	110
Sideswipe (same direction).....	2,394	7,114	8.2	6.5	95	61
Sideswipe (opposite direction).....	755	1,486	2.6	1.4	30	13
Turning movement.....	1,876	4,752	6.5	4.3	74	41
Parking maneuver and backing in traffic lane.....	2,411	7,768	8.3	7.1	96	67
All collisions.....	29,044	109,730	100.0	100.0	1,151	943

Table 4.—Comparison of direct costs of collisions between passenger cars or passenger cars and other motor vehicles in Utah during 1955 and Massachusetts during 1953, classified by type of collision

Type of collision	Total direct cost		Percent of total		Average cost per accident		Cost per 100 million vehicle-miles of travel	
	Utah	Mass.	Utah	Mass.	Utah	Mass.	Utah	Mass.
	(\$1,000)	(\$1,000)					(\$1,000)	(\$1,000)
Angle.....	6,596	17,386	37.9	41.6	\$666	\$327	261	150
Rear-end.....	6,058	10,842	34.8	25.9	573	482	240	63
Head-on.....	1,834	9,078	10.5	21.7	1,642	709	73	78
Sideswipe (same direction).....	1,157	1,958	6.7	4.7	483	276	46	17
Sideswipe (opposite direction).....	351	706	2.0	1.7	465	471	14	6
Turning movement.....	486	1,114	2.8	2.7	259	232	19	10
Parking maneuver and backing in traffic lane.....	919	732	5.3	1.7	381	94	36	6
All collisions.....	17,401	41,816	100.0	100.0	599	381	690	260

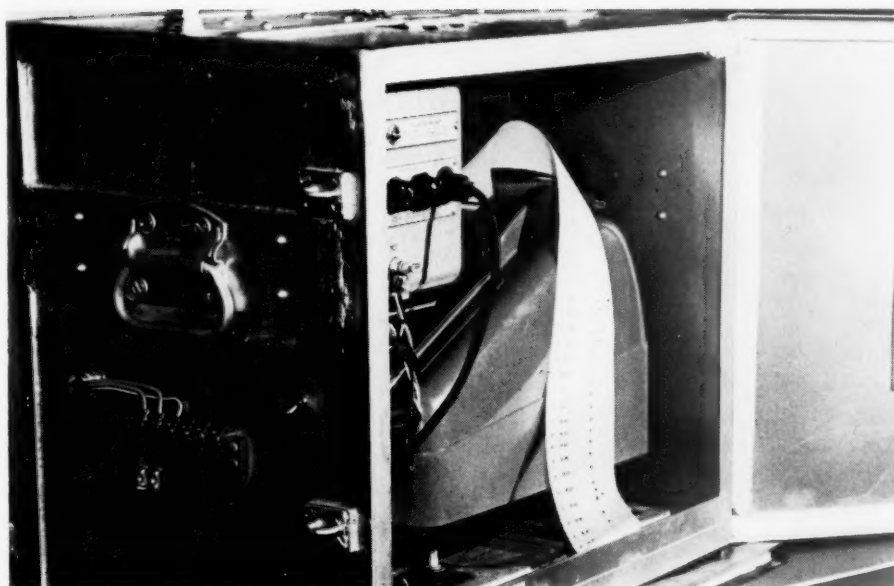


Figure 1.—Kilrec Timer (with panel door open).

ONE of the tedious tasks in research studies of portland cement concrete dual-drum paver operation is stop-watch timing of the paver cycle and mixing time. To do this job automatically, the Bureau of Public Roads recently developed a device which measures the elapsed time, in hundredths of a minute, of certain elements of the paver cycle, and prints the data on paper tape. The device, named the Kilrec Timer in recognition of its co-developers, M. J. Kilpatrick and W. N. Records, is assembled from commercially available components, including a printing timer, a suitable converter to provide 110-volt alternating current from the paver storage battery, and control circuits of relays, capacitors, and switches. The equipment is housed in a dustproof container with an external hookup panel. Intermittent demand for current is about 100 watts.

To operate the device, suitable switches, wired to the control mechanism, are attached to the transfer and discharge chutes of the paver. Closing of the transfer chute or opening of the discharge chute actuates the appropriate switch, which completes an electrical circuit and thereby causes the timer to record the time that has elapsed since the preceding switch actuation. The elapsed time and an indication of which switch closed, is automatically printed on a paper tape.

Figure 2 represents a section of tape, with interpreted data added on each side. On the tape itself, DT represents the closing of the transfer chute, and the time recorded opposite the symbol is the time interval from the opening of the discharge chute to the closing of the transfer chute. During this period only one batch is in the paver, in either the first or second compartment of the drum.

TD on the tape represents the opening of the discharge chute, and the time recorded opposite this symbol is the time interval from the closing of the transfer chute to the opening of the discharge chute. This is the period of simultaneous mixing, when there is a separate

batch in each of the two compartments of the drum. (The printing timer actually prints the digits 1 or 2 on the tape, but DT and TD are used in the illustration, with successively numbered subscripts, for clarity in the explanation that follows.)

Referring to figure 2, it may be seen how actual paver cycle time is derived from the tape. The first simultaneous mixing interval, TD_1 , was 0.26 minute. The next time interval, DT_2 , was 0.47 minute, and accounts for discharging time, transfer time, and any delay time in raising the skip. The sum of these, shown at the left of the tape, was 0.73 minute, and this was the time elapsed during that particular paver cycle.

The data in figure 2 were obtained on a paver whose batchmeter was set for a minimum mixing time of 0.90 minute (54 seconds) and a minimum paver cycle of 0.65 minute (39 seconds). From these values, it was calculated that the minimum simultaneous mixing time, TD, should be 0.33 minute and the minimum nonsimultaneous mixing time, DT, should be 0.32 minute. In the two columns at the extreme left of the tape, in figure 2, comparison is made of the actual elapsed time, as recorded, with these minimum values. For example, TD_1 , recorded on the tape as 0.26 minute, was 0.07 minute less than the minimum value of 0.33 minute. Minus signs indicate that the actual elapsed time was shorter than should be expected with the batchmeter setting; plus signs indicate longer elapsed time—that is, delays.

The total mixing time of each successive batch passing through the paver can also be derived from the data printed on the tape. The first batch recorded in figure 2, for example, entered the first compartment when the transfer chute closed, at the point in time represented by DT_1 . It had been mixing 0.26 minute when the discharge chute opened (TD_1) to discharge the preceding batch from the second compartment. Mixing continued for the batch in the first compartment while discharge was underway. By the time the

Automatic Time Recorder for Dual-Drum Paver Operation

transfer chute had opened and closed again, shifting the batch from the first to the second compartment, at DT_2 , another 0.47 minute had elapsed. When the discharge chute again opened, at TD_2 , beginning discharge of the batch into the bucket, 0.32 minute more had elapsed.

The total elapsed time recorded for this batch was $0.26 + 0.47 + 0.32 = 1.05$ minutes. However, from this total must be deducted the time lag between the moment of the first transfer chute closing and the entry of all solid material from the skip into the first compartment. This averages about 0.08 min-

Variance from minimum values based on batch- meter setting	Paver cycle time	Mixing time (minus 0.08)
TD = 0.33	DT = 0.32	
		T A P E
		DT ₁ .29
-.07	.73	TD ₁ .26
		DT ₂ .47
-.01	.71	TD ₂ .32
		DT ₃ .39
0	.65	TD ₃ .33
		DT ₄ .32
+.20	.85	TD ₄ .53
		DT ₅ .32
+.01	.63	TD ₅ .34
		DT ₆ .29
+.01	1.90	TD ₆ .34
		DT ₇ 1.56
+.01		TD ₇ .34

Figure 2.—A sample tape recorded by the Kilrec Timer, with interpreted data added.

ute. Hence the mixing time of this batch was $1.05 - 0.08 = 0.97$ minute, as shown at the right of the tape in figure 2.

From the illustration it can be seen that three batch mixing times, 0.97, 0.96, and 0.89 minute, were only a few seconds off the batchmeter set time. It will be noted, however, that there was considerable compensating fluctuation in the individual elapsed times of the three stages composing the total mixing time. The long mixing times of the third and fourth batches, 1.10 and 1.11 minutes, were due to the 0.20-minute delay in TD₄. In this step of the paver operation, the delay must have occurred in opening the discharge chute. The last batch illustrated had a mixing time of 2.16 minutes, due to the 1.24-

minute delay in DT₇. This delay, which must have occurred in raising the skip, resulted in a mixing time almost $2\frac{1}{2}$ times the batchmeter setting.

It is evident from this explanation of the data that can be derived from the Kilree Timer tape, that the device readily produces the following information:

1. The mixing time for individual batches of concrete.
2. The paver cycle time.
3. The frequency and duration of delays, and whether they occur at the skip or at the discharge chute.
4. The location of the individual batches, insofar as mixing time is concerned, in relation to other batches produced during the

period that the timer is attached to the paver.

While the Kilree Timer was developed for use in research, it could also readily be employed, either by the contractor or the contracting authority's inspector, and either on the job while the paver is operating or later, for purposes of checking the operation of the paver and comparisons of actual with specified mixing time.

Details as to the components and circuitry used in building the Kilree Timer may be obtained by writing to the Highway Needs and Economy Division, Bureau of Public Roads, Washington 25, D.C. The cost of the components and materials used in the recorder built by Public Roads was approximately \$900, of which \$750 was for the printing timer.

The Economic Cost of Traffic Accidents in Relation to the Highway Systems

(Continued from page 43)

traffic, there was some variation from the 1955 curves. Values on the uncontrolled-access highways were somewhat lower than the curve in this volume range. One explanation for this may be that the over-crowding of the uncontrolled-access roads actually tends to prevent certain types of collisions.

Data for only one section of the controlled-access highways in this high volume range

were available—Route 128, a section of the northern circumferential highway near Boston. This section of highway, although opened in 1952, has been reaching capacity and it is now being improved to higher standards. The accident rate on this highway section was 161.7 accidents per 100 million vehicle-miles in 1957. This was double the rate in 1953—accident costs per mile had increased from \$19,100 in 1955 to \$30,100 in 1957. When

improvement of this section is completed there should be, without doubt, a reversal of the upward trend.

In summation, it may be stated that the low accident rates and costs on the controlled-access highways are consistent with previous findings. These highways most certainly contribute their part in maintaining a comparatively low accident rate on the State highways in the Federal-aid primary system.

Highway Statistics, 1958

The Bureau's *Highway Statistics, 1958* is now available. The bulletin, the fourteenth of an annual series, presents the 1958 statistical and analytical tables of general interest on motor fuel, motor vehicles, highway-user taxation, State and local highway finance,

highway mileage, and Federal aid for highways.

Included in the 1958 bulletin are motor-vehicle travel data for 1957 and 1958, data on contract bid prices for rural Federal-aid highway construction, and mileage data and status of the National System of Interstate Highways. In addition, there is included the status of the Highway Trust Fund, which

gives the contributions and expenditures on a current basis.

The 150-page publication may be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., at \$1.00 a copy. The series of annual bulletins that are available from the Superintendent of Documents are indicated on the inside back cover of PUBLIC ROADS.

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Annual Reports of the Bureau of Public Roads:

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REPORTS TO CONGRESS

A Report of Factors for Use in Apportioning Funds for the National System of Interstate and Defense Highways, House Document No. 300 (1958). 15 cents.

Consideration for Reimbursement for Certain Highways on the Interstate System, House Document No. 301 (1958). 15 cents.

Factual Discussion of Motortruck Operation, Regulation, and Taxation (1951). 30 cents.

Federal Role in Highway Safety, House Document No. 93 (1959). 60 cents.

First Progress Report of the Highway Cost Allocation Study, House Document No. 106 (1957). 35 cents.

Highway Needs of the National Defense, House Document No. 249 (1949). 50 cents.

Interregional Highways, House Document No. 379 (1944). 75 cents.

Local Rural Road Problem (1950). Out of print.

Needs of the Highway Systems, 1955-84, House Document No. 120 (1955). 15 cents.

Progress and Feasibility of Toll Roads and Their Relation to the Federal-Aid Program, House Document No. 139 (1955). 15 cents.

Progress Report on the Federal-Aid Highway Program, House Document No. 74 (1959). 70 cents.

Public Utility Relocation Incident to Highway Improvement, House Document No. 127 (1955). 25 cents.

Third Progress Report of the Highway Cost Allocation Study, House Document No. 91 (1959). 35 cents.

PUBLICATIONS

Catalog of Highway Bridge Plans (1959). \$1.00

Construction of Private Driveways, No. 272MP (1937). 15 cents.

Criteria for Prestressed Concrete Bridges (1954). 15 cents.

Design Capacity Charts for Signalized Street and Highway Intersections (reprint from *PUBLIC ROADS*, Feb. 1951). 25 cents.

Financing of Highways by Counties and Local Rural Governments: 1942-51. 75 cents.

General Location of the National System of Interstate Highways, Including All Additional Routes at Urban Areas Designated in September 1955. 55 cents.

Highway Bond Calculations (1936). 10 cents.

Highway Capacity Manual (1950). \$1.00.

Highway Statistics (published annually since 1945):
1955, \$1.00. 1956, \$1.00. 1957, \$1.25. 1958, \$1.00.

Highway Statistics, Summary to 1955. \$1.00.

Highways of History (1939). 25 cents.

Legal Aspects of Controlling Highway Access (1945). 15 cents.

Manual on Uniform Traffic Control Devices for Streets and Highways (1948) (including 1954 revisions supplement). \$1.25.

Revisions to the Manual on Uniform Traffic Control Devices for Streets and Highways (1954). *Separate*, 15 cents.

Parking Guide for Cities (1956). 55 cents.

Public Control of Highway Access and Roadside Development (1947). 35 cents.

Public Land Acquisition for Highway Purposes (1943). 10 cents.

Results of Physical Tests of Road-Building Aggregate (1953). \$1.00.

Selected Bibliography on Highway Finance (1951). 60 cents.

Specifications for Aerial Surveys and Mapping by Photogrammetric Methods for Highways, 1958: a reference guide outline. 75 cents.

Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects, FP-57 (1957). \$2.00.

Standard Plans for Highway Bridge Superstructures (1956). \$1.75.

The Role of Aerial Surveys in Highway Engineering (1960). 40 cents.

Transition Curves for Highways (1940). \$1.75.

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